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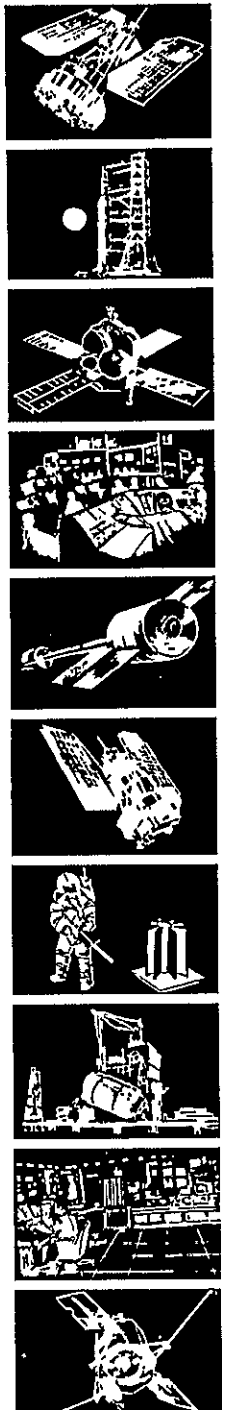


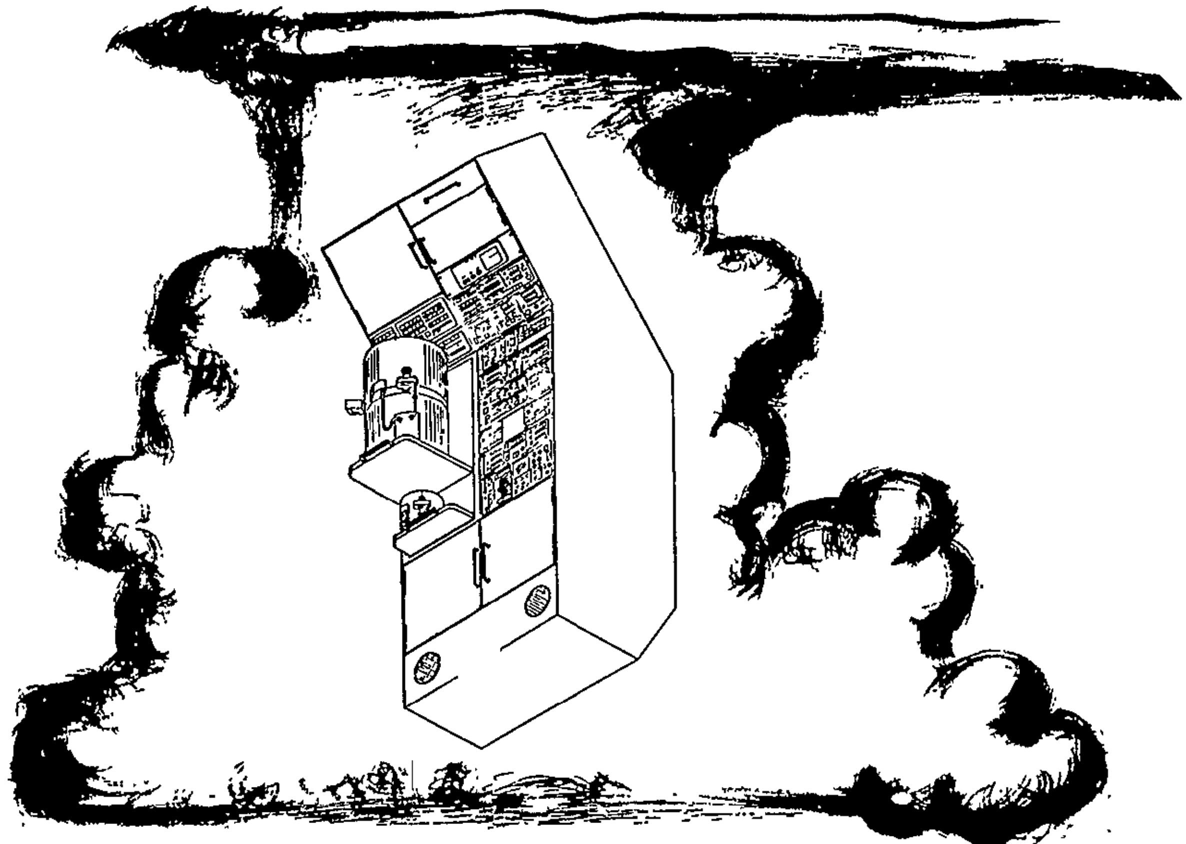
14 APRIL 1976

Final Definition And Preliminary Design Study for The Initial

ATMOSPHERIC CLOUD PHYSICS LABORATORY

A Spacelab Mission Payload

NAS 8-31845



(NASA-CR-144274) ATMOSPHERIC CLOUD PHYSICS LABORATORY. REQUIREMENTS REVIEW PRESENTATION Final Definition and Preliminary Design Study (General Electric Co.) 96 p HC $5.00 CSCL 22B

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REQUIREMENTS REVIEW PRESENTATION

DR-MA-03

GENERAL ELECTRIC

14 APRIL 1976

FINAL DEFINITION AND PRELIMINARY DESIGN STUDY

FOR THE INITIAL ATMOSPHERIC CLOUD PHYSICS LABORATORY - A SPACELAB MISSION PAYLOAD

NAS 8-31845

REQUIREMENTS REVIEW
PRESENTATION

DR--MA--03

For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

by

GENERAL ELECTRIC
SPACE DIVISION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

ATMOSPHERIC CLOUD PHYSICS LABORATORY

THE REQUIREMENTS REVIEW EFFORT PERFORMED BY GENERAL ELECTRIC FOR THE ACPL PHASE B STUDY WILL CONSIST OF THE FOLLOWING:

- INTRODUCTION / STUDY OVERVIEW - ROBERT GRECO
- ACPL SCIENTIFIC REQUIREMENTS - DR. LARRY EATON
- SYSTEMS/SUBSYSTEMS REQUIREMENTS - GORDON FOGAL
- SUMMARY - ROBERT GRECO

THE MATERIAL CONTAINED IN THIS DOCUMENT AND PRESENTED AT THE REQUIREMENTS REVIEW CONDUCTED AT MSFC ON 14 APRIL 1976 WAS FORMULATED TO PROVIDE A PROGRAM REVIEW OF THE REQUIREMENTS PACKAGE FOR THE ACPL PHASE B STUDY.

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ATMOSPHERIC

CLOUD

PHYSICS

LABORATORY

Final Definition and Preliminary Design Study

REQUIREMENTS REVIEW

APRIL 14, 1976

SPACE DIVISION

ACPL

STUDY OVERVIEW
R. GRECO

SCIENTIFIC REQUIREMENTS
L. EATON

SYSTEM/ SUBSYSTEM
G. FOGAL

SUMMARY
R. GRECO

ACPL STUDY SUMMARY FLOW

The study task flow is shown with progress to date identified. The extension of Task 1, and the anticipated rescheduling of the Concept Review, to accomodate the evolving Scientific Functional Requirements, is shown.

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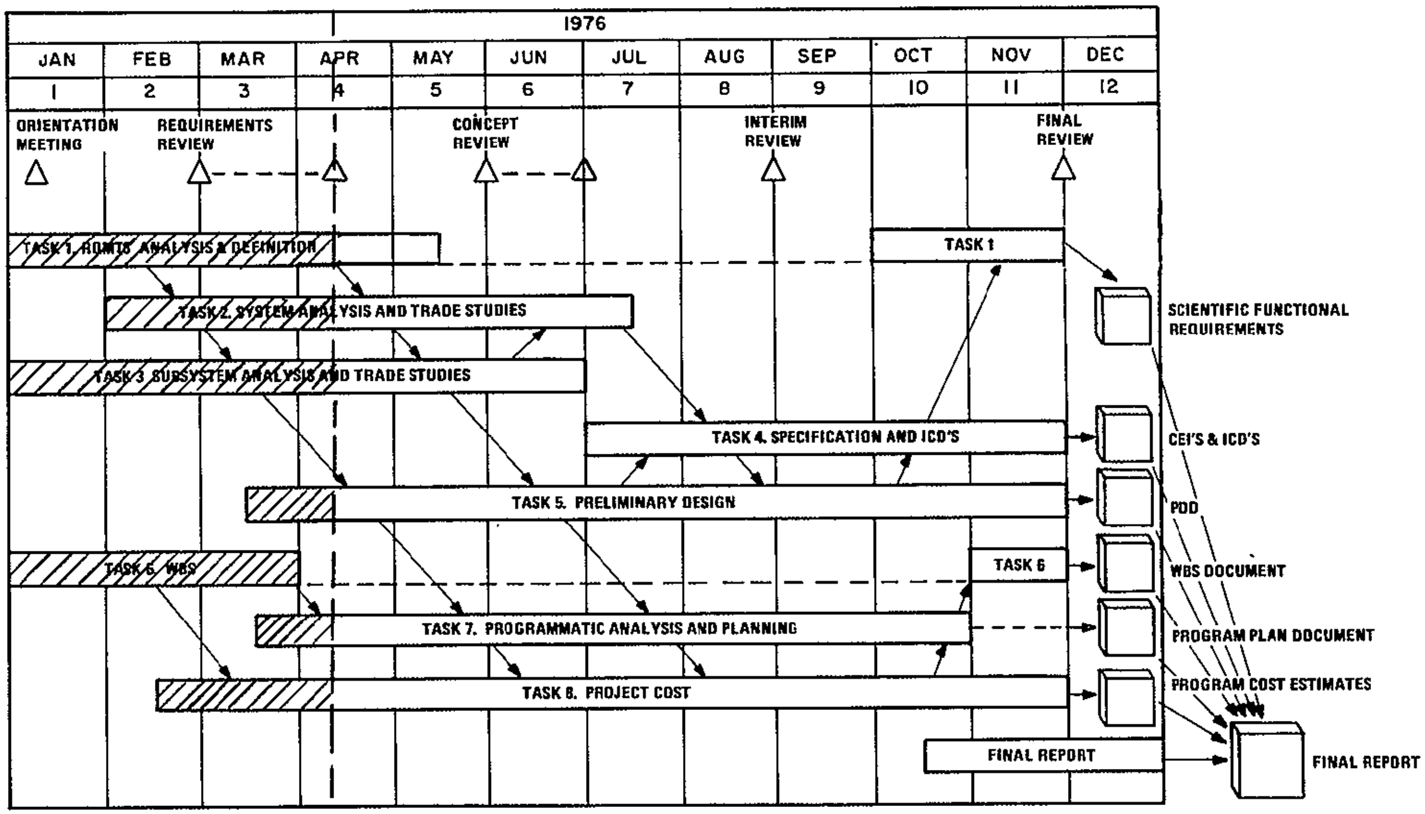
ACPL STUDY SUMMARY FLOW

ACPL



- STUDY PLAN
- WBS
- GROUND RULES AND GUIDELINES
- PERFORMANCE REQUIREMENTS

- SCIENCE REQUIREMENTS (PRELIMINARY)
- FLIGHT & GROUND SUPPORT EQUIPMENT REQUIREMENTS (PRELIM)
- MISSION/PAYLOAD REQUIREMENTS (PRELIM)
- COST TARGETS

- SCIENCE EQUIPMENT REQUIREMENTS
- FLIGHT & GROUND SUPPORT EQUIPMENT CONCEPT
- MISSION & PAYLOAD PLAN (PRELIMINARY)
- SYS/SUBSYS ANALYSIS & TRADES
- PERFORMANCE/COST ESTIMATES (PRELIM)
- OPERATIONS ANALYSIS (PRELIMINARY)
- IDENTIFICATION OF CRITICAL AREAS/ COMPONENTS

- PRELIM CEI'S & ICD'S ON HARDWARE FOR INITIAL FLIGHTS
- INTERIM DESIGN OF FLT & GROUND SUPPORT EQPT FOR INITIAL FLIGHTS
- INTERIM DESIGN OF LAB FOR INITIAL FLIGHTS
- INTERIM COST ESTIMATE
- COMPATABILITY WITH FOLLOW ON FLIGHT PROGRAM

- PAYLOAD DEFINITION
- PRELIMINARY DESIGN FOR INITIAL PAYLOAD & SUPPORT EQUIPMENT
- PRELIMINARY CEI'S AND ICD'S
- OPERATIONS ANALYSIS (FINAL)
- COST ESTIMATES (FINAL)
- RISK ANALYSIS
- IDENTIFY LONG LEAD PROCUREMENT ITEMS

STUDY STATUS

The major efforts, to date, are identified. All topic areas will be reviewed with appropriate NASA, MSFC personnel. The formal presentation places emphasis on those areas of primary concern to the Scientific Advisory Subcommittee.

STUDY STATUS

- o SCIENTIFIC FUNCTIONAL REQUIREMENTS DEFINITION PROCEEDING
  - O SCIENTIFIC EQUIPMENT SUBSYSTEMS
  - O FLIGHT SUPPORT SUBSYSTEMS
- o SYSTEMS ANALYSES/TRADE STUDIES
  - O S/L CAPABILITIES
  - O MMSE
  - O OPERATIONS ANALYSIS
- o SUBSYSTEM ANALYSIS/TRADE STUDIES
  - O SCIENTIFIC SUBSYSTEMS
    - O CHAMBERS
    - O HUMIDIFIER
    - O THERMAL CONTROL
    - O DATA MANAGEMENT
- o ACPL PRELIMINARY DESIGN
  - O CONCEPT
  - O SPECIFICATIONS/ICD'S
- o PROGRAMMATICS
  - O COST
  - O SCHEDULE
  - O WBS

PRELIMINARY INITIAL ACPL

The concept for the Initial ACPL is shown. The Scientific Subsystems identified have been revised in accordance with the latest requirements provided by the Scientific Advisory Subcommittee.

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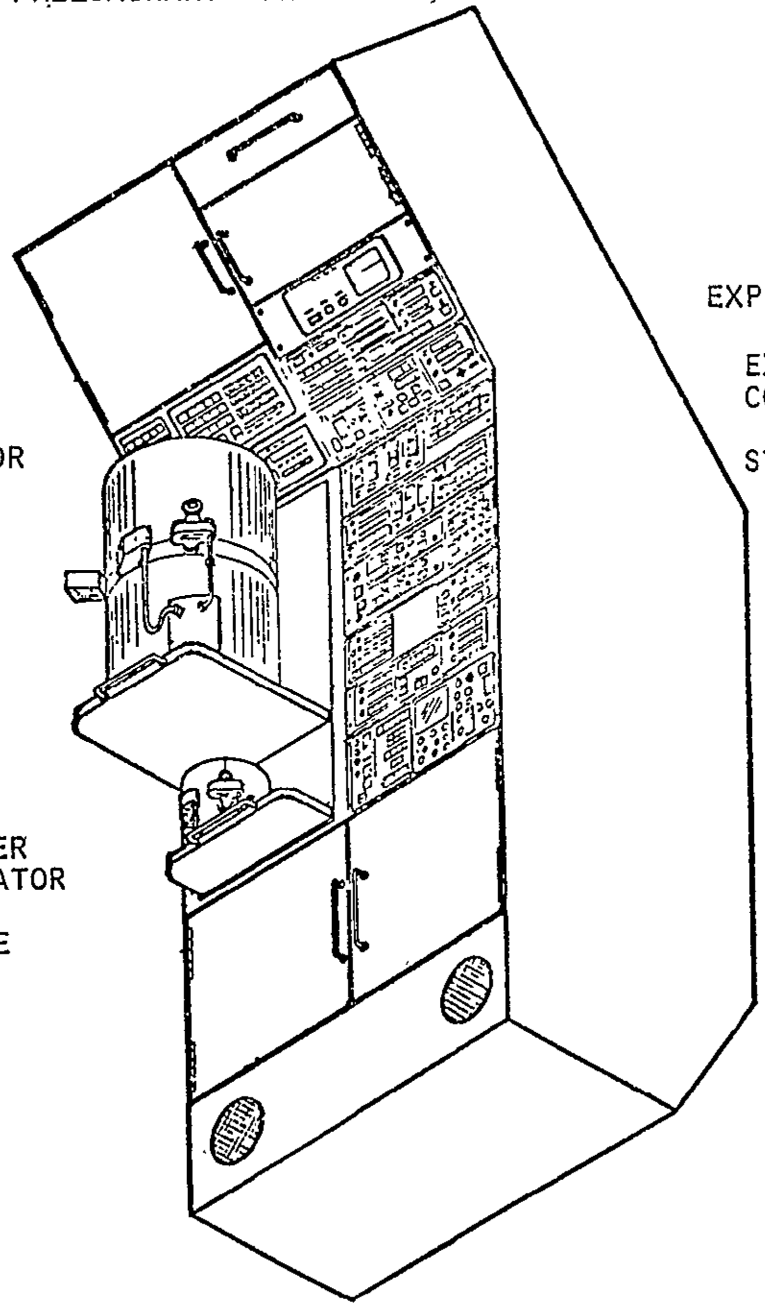
ACPL

PRELIMINARY INITIAL ACPL



AEROSOL GENERATORS

- EVAPORATOR/CONDENSER GENERATOR (AITKEN)
- PHOTO/CHEMICAL GENERATOR

EXPERIMENT CHAMBERS

- EXPANSION CHAMBER
- CONTINUOUS FLOW DIFFUSION CHAMBER
- STATIC DIFFUSION LIQUID CHAMBER

AEROSOL CHARACTERIZERS

- OPTICAL PARTICLE COUNTER
- ELECTROSTATIC PRECIPITATOR SAMPLER
- ELECTRICAL AEROSOL SIZE ANALYZER

OPTICAL AND IMAGING DEVICES

- CAMERA (35 MM)
- LIGHT SOURCE

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ACPL

SCIENTIFIC REQUIREMENTS

L. Eaton

- ACPL PERSPECTIVE
- SCIENTIFIC FUNCTIONAL REQUIREMENTS
- INITIAL ACPL SUBSYSTEM SELECTIONS
- PRELIMINARY ACPL GROWTH CONCEPT

ACPL PERSPECTIVE

AN ATMOSPHERIC MICROPHYSICS OPPORTUNITY

ACPL SCOPE: INITIAL AND GROWTH

The ACPL program is presently conceived and structured as an evolving, growing facility which will provide complementary and supplementary research support to terrestrial laboratory in the area of Atmospheric Microphysics. The ACPL program offers a unique low gravity environment which can be utilized to enhance Atmospheric Microphysics Laboratory investigations.

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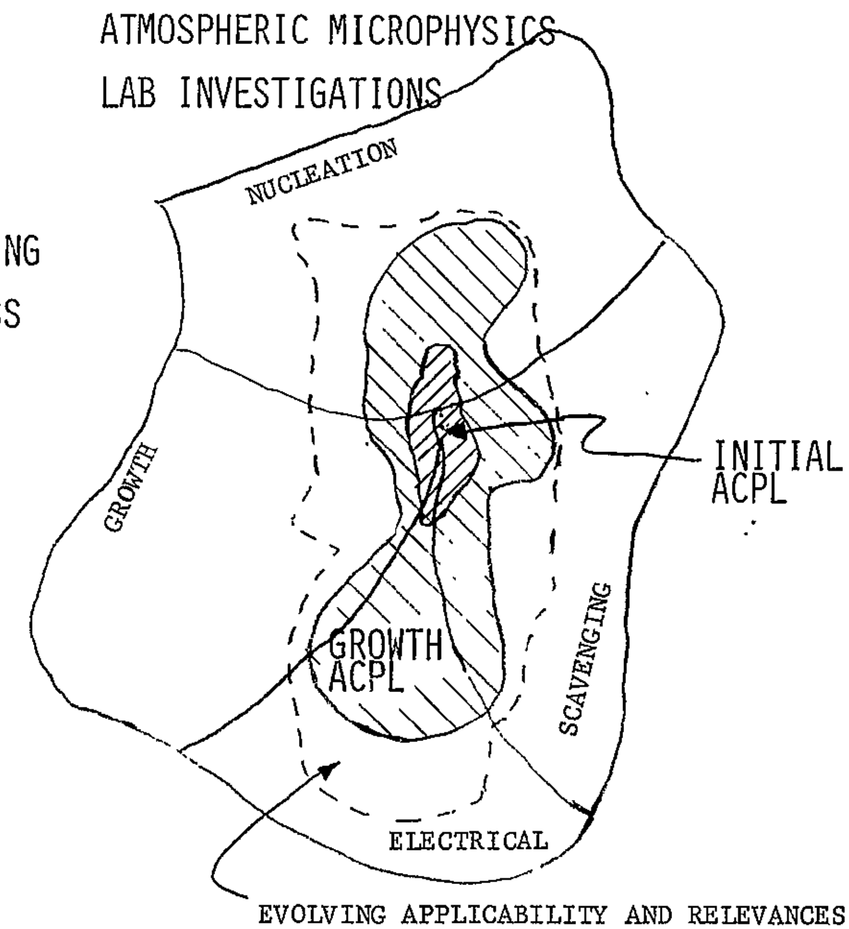
ACPL SCOPE: INITIAL AND GROWTH

ACPL

- ACPL TO COMPLEMENT AND SUPPLEMENT TERRESTRIAL LABORATORIES
- INITIAL ACPL DIRECTED TOWARD SEGMENTS OF NUCLEATION, GROWTH AND POSSIBLY SCAVENGING
- EXTENSION OF ACPL CAPABILITY WILL INCOMPASS WIDER EXPERIMENT OBJECTIVES
- EVOLVING PERSPECTIVE: SIMPLE TO COMPLEX
  WARM TO COLD
  NEUTRAL TO CHARGE AND POLLUTION



Z-G CLOUD PHYSICS APPLICATIONS

A number of important Atmospheric Microphysics phenomena are gravity independent, wherein low-acceleration environment derived data are directly relatable to our 1-g terrestrial environment. Some aspects of certain gravity dependent phenomena can be enlightened through the use of techniques such as controlled acceleration and separation of variables (e.g. dynamic versus diffusional). Maintenance of a broad perspective during the present design phase will greatly enhance the future usefulness of the ACPL facility.

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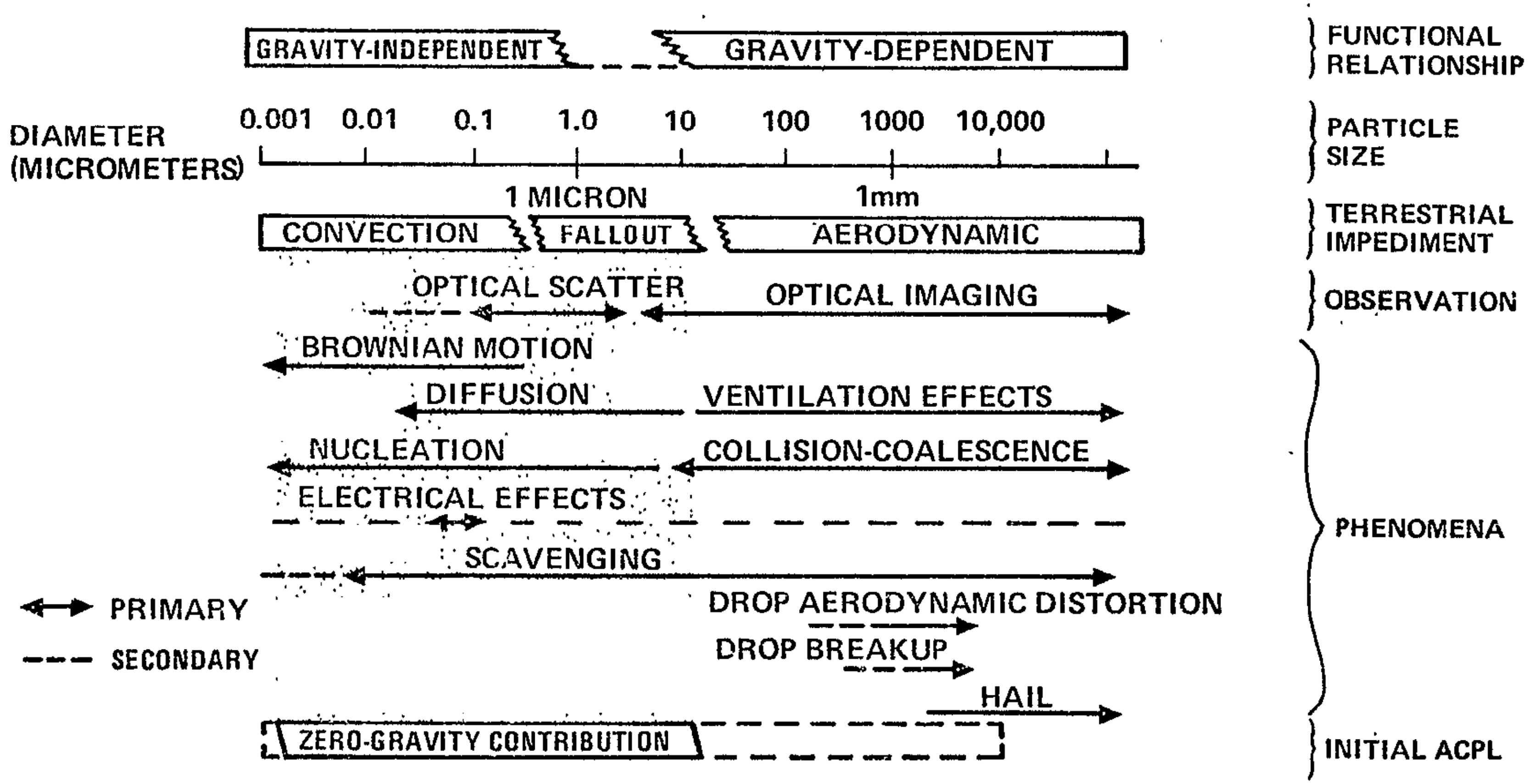
ACPL

ZERO-GRAVITY CLOUD PHYSICS APPLICATIONS



- SOME ATMOSPHERIC MICROPHYSICS PHENOMENA ARE GRAVITY INDEPENDENT
- SOME ASPECTS OF GRAVITY DEPENDENT PHENOMENA MAY BE ENHANCED BY A LOW-G ENVIRONMENT
- THUS MAINTAIN BROAD PERSPECTIVE AS TO FULL ACPL GROWTH POTENTIAL

ACPL EXPERIMENT PROGRAM LISTING

The twenty classes are not independent in the atmosphere or in the experiment laboratory. Their separation is useful for the definition of the potential requirements for the full ACPL program. This broad viewpoint will enhance the incorporation of new experiment approaches and experiment areas as their relevances evolve with time.

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ACPL EXPERIMENT PROGRAM LISTING

EXPERIMENT CLASS NO.	EXPERIMENT CLASS TITLE	DESIGNATION
1	CONDENSATION NUCLEATION	CN
2	ICE NUCLEATION	IN
3	ICE MULTIPLICATION	IM
4	CHARGE SEPARATION	CS
5	ICE CRYSTAL GROWTH HABITS	ICG
6	SCAVENGING	S
7	RIMING AND AGGREGATION	RA
8	DROPLET ICE CLOUD INTERACTIONS	DIC
9	HOMOGENEOUS NUCLEATION	HN
10	COLLISION INDUCED FREEZING	CIF
11	SATURATION VAPOR PRESSURE	SVP
12	ADIABATIC CLOUD EXPANSION	ACE
13	ICE NUCLEI MEMORY	INM
14	TERRESTRIAL EXPANSION CHAMBER EVALUATION	ECE
15	CONDENSATION NUCLEI MEMORY	CNM
16	NUCLEI MULTIPLICATION	NM
17	DROP COLLISION BREAKUP	DCB
18	COALESCENCE EFFICIENCIES	CE
19	STATIC DIFFUSION CHAMBER EVALUATION	SDC
20	UNVENTILATED DROPLET DIFFUSION COEFFICIENTS	UDD

- CLASSES ARE NOT INDEPENDENT BUT CERTAIN ASPECTS OF EACH MAY REQUIRE ISOLATION
- ATMOSPHERIC MICROPHYSICS PRIORITIES CHANGE
- FAMILIARITY WITH Z-G WILL GIVE RISE TO NEW APPROACHES AND "RELEVANCE"
- THUS PROJECTED CAPABILITY FOR LOW Z-G RELAVENCE MAY ALLOW FOR VITAL TECHNIQUES LATER

SCIENTIFIC FUNCTIONAL

REQUIREMENTS

INITIAL ACPL EXPERIMENT PROGRAM APPROACH

Experiment suggestions were screened by a number of criteria during Phase A of the ACPL program. Present screening is directed toward the identification of "simple", "relevant" experiments for the initial ACPL flights. This screening also provides experiment selection for future missions.

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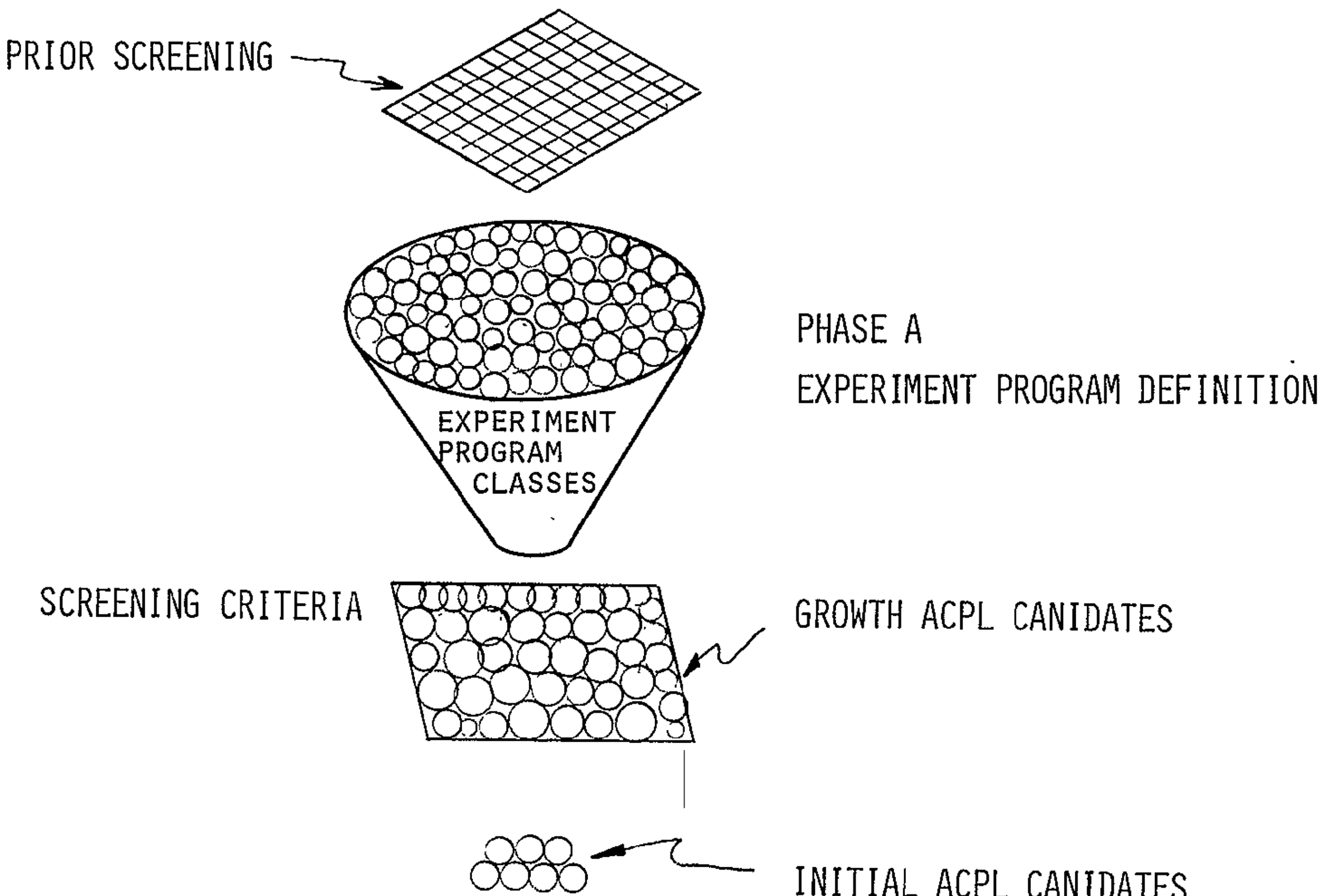
INITIAL ACPL EXPERIMENT PROGRAM APPROACH

ACPL



- O "SIMPLE", "RELEVANT" EXPERIMENTS EXIST FOR INITIAL ACPL
- O GROWTH DIRECTIONS ARE IDENTIFIED

SCREENING CRITERIA

The facing chart gives a few of the factors that must be considered during the selection of the experiments for the initial and subsequent missions.

SCREENING CRITERIA

- STUDY DEFINED SCOPE OF RESEARCH
- GROWTH
- FLEXIBILITY
- LOW COST
- EVOLVING SCIENTIFIC REQUIREMENTS

+

- SUBJECTIVE FACTORS
    - SCIENCE PRIORITY
    - ACHIEVEMENT ABILITY
    - ON ORBIT EXPERIMENT TIME
    - ZERO G APPLICABILITY

⇓

- INITIAL ACPL EXPERIMENT COMPLEMENT

STRAWMAN: EXPERIMENT FUNCTIONAL REQUIREMENTS

To maintain an overall perspective on the projected full ACPL requirements, a strawman functional requirements document was generated for the twenty experiment classes. The NASA provided Scientific Functional Requirements as they existed in March 1976 were incorporated. This information was then used to generate a detailed Initial ACPL System/Subsystem Performance Requirements document. This effort also identified the need for expanded functional requirements as relevant to the Initial ACPL missions.

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STRAWMAN
EXPERIMENT FUNCTIONAL REQUIREMENTS

ACPL

GE GENERATED (PRELIMINARY)

- o TITLE
- o OBJECTIVE
- o DISCUSSION (PROCESSES)
- o ENVIRONMENT
- o INPUTS
- o OUTPUTS
- o SUPPORTIVE DATA
- o DATA ACCURACY

SCIENCE ADVISORS
INPUTS INCORPORATED

- O SCIENTIFIC EQUIPMENT SELECTION
  - O CHAMBERS
  - O GENERATORS
  - O CHARACTERIZERS
  - O OPTICS/IMAGING DEVICES
- O FUNCTIONAL EQUIPMENT LAYOUT
  - O PURGE
  - O PREPARATION
  - O OPERATION
  - O CLEANSE

APRIL 1976

- o PROJECTED ACPL EQUIPMENT REQUIREMENTS OUTLINED
- o INITIAL ACPL EQUIPMENT REQUIREMENTS DEFINED
- o EXPANDED FUNCTIONAL REQUIREMENTS REQUIRED

EXAMPLE

EXPERIMENT FUNCTIONAL REQUIREMENTS CONSIDERATION

The functional requirements are best specified around key experiment and the associated experiment objectives. These experiments can be visualized as the injection of some material into a well defined volume with subsequent observations of the changes which occur within the volume. The functional requirements related to the Input, Experiment Environment and Output as well as the necessary supportive data must be specified.

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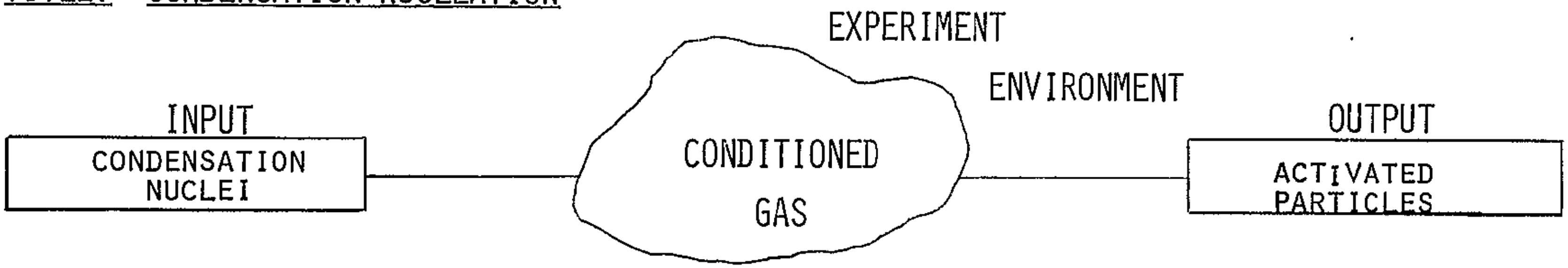
ACPL

EXAMPLE
EXPERIMENT FUNCTIONAL REQUIREMENTS CONSIDERATION

TITLE: CONDENSATION NUCLEATION



DATA

NUCLEI SIZE DISTRIBUTION	T,P,S	PARTICLE COUNT & SIZE VS TIME

- FUNCTIONALLY -MATERIAL IS INJECTED INTO A WELL DEFINED VOLUME, OUTPUT CONSISTS OF OBSERVING CHANGES WITHIN VOLUME
- SUPPORTIVE DATA REQUIRED FOR INTERPRETATION OF OBSERVED RESULTS

INITIAL ACPL

SUBSYSTEM SELECTIONS

SUBSYSTEM SELECTION

CONDENSATION NUCLEATION

INPUT

The input to this experiment consists of submicrometer (possibly up to ten micrometer) diameter particles in an aerosol form. A single generation technique will not provide the diverse types or size range of potential interest. The required characterization (e.g., size, concentration and surface properties) will be a function of the generator repeatability. NaCl and H_2SO_4 have been specified for the initial missions.

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ACPL

SUBSYSTEM SELECTIONS

CONDENSATION NUCLEATION INPUT

- O LARGE SIZE RANGE
- O MANY MATERIAL TYPES
- O REQUIRES CHARACTERIZATION

⇒

- NaCl, AgI, $CaCl_2$, Smoke → HOT-WIRE DILUTION CONDITIONING
- $(NH_4)_2 SO_4$, $H_2 SO_4$ → PHOTO/CHEMICAL DILUTION CONDITIONING
- LATEX, DOP → VIBRATING ORIFICE ATOMIZER DILUTION
- TELFON, DUST → POWDER DISPERSION DILUTION
- EARTH SAMPLE → PRE-LAUNCH AIR SAMPLE

→ PARTICLE CHARACTERIZERS

EAA, EAS (ANC)

- O INITIAL ACPL REQUESTS NaCl AND $H_2 SO_4$
- O ARTIFICIAL GENERATION OF $N = CS^k$ MUST BE VERIFIED ——INITIAL ACPL
- O $H_2 SO_4$, PRESENTS CORROSIVE CONSIDERATIONS
- O SUBMICROMETER PARTICLES PRESENT MEASUREMENT DIFFICULTIES

SUBSYSTEM SELECTIONS

CONDENSATION NUCLEATION

CHAMBERS AND OUTPUT

For the experiments directed toward assessing, e.g., the condensation accommodation coefficient, the variation of single variable at a time is important. When the combined assessment of varing R H, T, and P is the primary objective as in the adiabatic expansion experiment, then the Expansion Chamber (E) would be selected. Comparisons between the Static Diffusion Liquid (SDL) and CFD might provide information useful for terrestrial operation analysis.

SUBSYSTEM SELECTIONS

CONDENSATION NUCLEATION CHAMBERS AND OUTPUT

EXPERIMENT ENVIRONMENT (CHAMBERS)

- T, P, S, ⇨ E, CFD, SDL,
- VARY ONE VARIABLE ⇨ CFD, SDL
- MAX. REAL TIME THROUGHPUT ⇨ CFD

⇨ CDF (INTERCOMPARISONS WITH SDL MAY BE VERY USEFUL)

OUTPUT

- HIGH REAL TIME THROUGHPUT WITH NUMBERS AND SIZE DISTRIBUTORS

⇨ OPTICAL PARTICLE COUNTER

- CFD WITH OPTICAL PARTICLE COUNTER SATISFIES PRELIMINARY FUNCTIONAL REQUIREMENTS
- SDL, DUE TO ITS TERRESTRIAL USE, MAY PROVIDE USEFUL COMPARISONS WITH CFD

SUBSYSTEM SELECTIONS

CONDENSATION NUCLEATION

SUPPORT AND MONITORING

Particle and organic free air are known to be important. Functional definition as to tolerable levels have not yet been specified. Additionally, further conditions or restraints on the lowest RH desired and the level of CO_2 that is acceptable must be clarified.

SUBSYSTEM SELECTIONS

CONDENSATION NUCLEATION

SUPPORT AND MONITORING

SUPPORT EQUIPMENT

- CLEAN AIR (PARTICLES, ORGANICS)
- T, P

⇨ AIR PRE-POST CONDITIONING
THERMAL CONTROL
PRESSURE CONTROL

EXPERIMENT MONITORING

- RECORD INPUT, OUTPUT & ENVIRONMENT PARAMETERS

⇨ T, P, S (T) SENSORS AND READOUTS
SIZE DISTRIBUTIONS READOUT

- LEVEL OF ORGANIC REMOVAL NEEDS TO BE SPECIFIED
- INITIAL R. H. LEVEL DESIRED NEEDS TO BE SPECIFIED
- DESIRED CO_2 LEVEL NEEDS TO BE SPECIFIED

ACPL EXPERIMENT PROGRAM LISTING

The equipment selection on the basis of the March 1976 Scientific requirements will provide a capability of performing portions of the experiments marked on the facing chart. A number of these experiments would be better performed in a chamber other than the E, CFD or SDL chambers presently identified for the Initial ACPL.

For example, ice crystal growth habits or long term scavenging by ice would be better suited in the SDI chamber. The expansion chamber would permit the growth of small ice crystals but the results would be qualitative as to its actual water vapor environment.

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ACPL EXPERIMENT PROGRAM LISTING

ACPL

	EXPERIMENT CLASS NO.	EXPERIMENT CLASS TITLE	DESIGNATION
*	1	CONDENSATION NUCLEATION	CN
**	2	ICE NUCLEATION	IN
**	3	ICE MULTIPLICATION	IM
	4	CHARGE SEPARATION	CS
**	5	ICE CRYSTAL GROWTH HABITS	ICG
**	6	SCAVENGING	S
	7	RIMING AND AGGREGATION	RA
**	8	DROPLET ICE CLOUD INTERACTIONS	DIC
	9	HOMOGENEOUS NUCLEATION	HN
	10	COLLISION INDUCED FREEZING	CIF
	11	SATURATION VAPOR PRESSURE	SVP
*	12	ADIABATIC CLOUD EXPANSION	ACE
	13	ICE NUCLEI MEMORY	INM
*	14	TERRESTRIAL EXPANSION CHAMBER EVALUATION	ECE
**	15	CONDENSATION NUCLEI MEMORY	CNM
*	16	NUCLEI MULTIPLICATION	NM
	17	DROP COLLISION BREAKUP	DCB
	18	COALESCENCE EFFICIENCIES	CE
*	19	STATIC DIFFUSION CHAMBER EVALUATION	SDC
*	20	UNVENTILATED DROPLET DIFFUSION COEFFICIENTS	UDD

* INITIAL ACPL

* PARTIAL ACCOMPLISHMENT ON INITIAL ACPL

INITIAL ACPL FUNCTIONAL FLOW DIAGRAM

A simplified function diagram for the Initial ACPL is shown on the facing page. Aerosol flow through or around the humidifier prior to chamber injection is provided.

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INITIAL ACPL FUNCTIONAL FLOW DIAGRAM

ACPL

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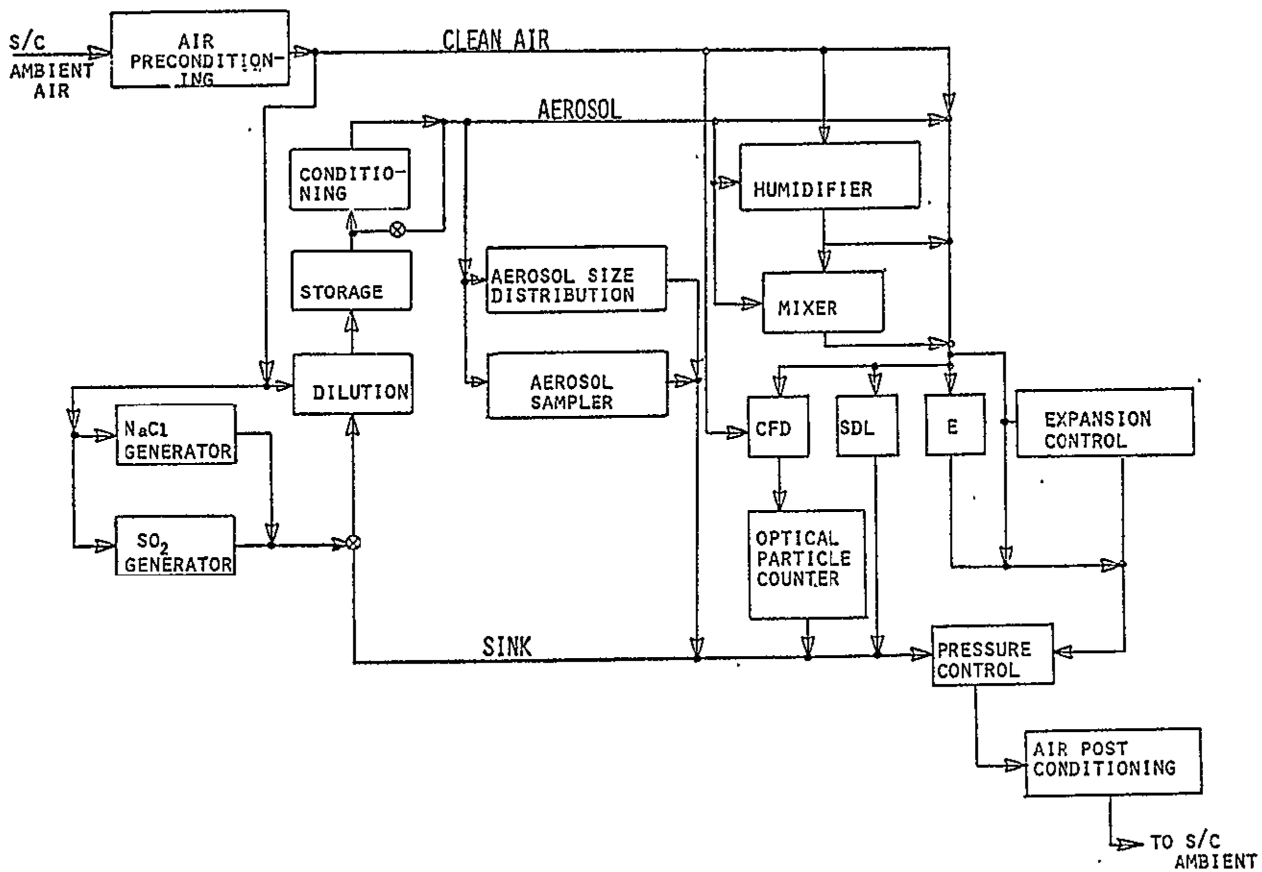

PRELIMINARY

ACPL GROWTH

CONCEPT

PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

Based on the initial NASA specified chambers, the adjacent chart provides the presently envisioned equipment complement for the Initial ACPL and subsequent early growth. Interchange among these components can be made without a large impact of the system. A representative experiment capability is also provided. The absolute experiment list will vary as a function of experiment objectives and experiments approach.

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PRELIMINARY EVOLUTIONARY GROWTH CONCEPT

ACPL

	PRIMARY EQUIPMENT CANDIDATES	
	INITIAL ACPL	INITIAL GROWTH
EXPERIMENT CHAMBERS	EXPANSION CHAMBER CONTINUOUS FLOW DIFFUSION CHAMBER STATIC DIFFUSION LIQUID CHAMBER	STATIC DIFFUSION ICE CHAMBER
PARTICLE GENERATORS	EVAPORATOR/CONDENSER GENERATOR (AITKEN) PHOTO/CHEMICAL GENERATOR	VIBRATING ORIFICE GENERATOR
PARTICLE DETECTORS AND CHARACTERIZERS	OPTICAL PARTICLE COUNTER ELECTROSTATIC PRECIPITATOR SAMPLER ELECTRICAL AEROSOL SIZE ANALYZER	CONDENSATION NUCLEI COUNTER (AITKEN) MICROPOROUS FILTER
OPTICAL AND IMAGING DEVICES	CAMERA (35 MM) LIGHT SOURCE	VIDEO CAMERA STEREO MICROSCOPE
EXPERIMENT CAPABILITY		
PRIMARY	CN(1), ACE (12), ECE (14), NM (16) SDC (19), UDD (20)	IN (2), IM (3), ICG (5), CNM (15)
SECONDARY	IN (2), IM (3), ICG (5), S (6) DIC (8), CNM (15)	INM (13), NM (16) CIF (10)

PRELIMINARY EVOLUTIONARY GROWTH CONCEPT (CONT)

This chart relates other equipment that would be compatable with the ACPL system and could be included during the growth of the ACPL program. The Advance Equipment requires either advance development or special considerations before their enclusion into the ACPL facility.

PRELIMINARY EVOLUTIONARY GROWTH CONCEPT (CONT)

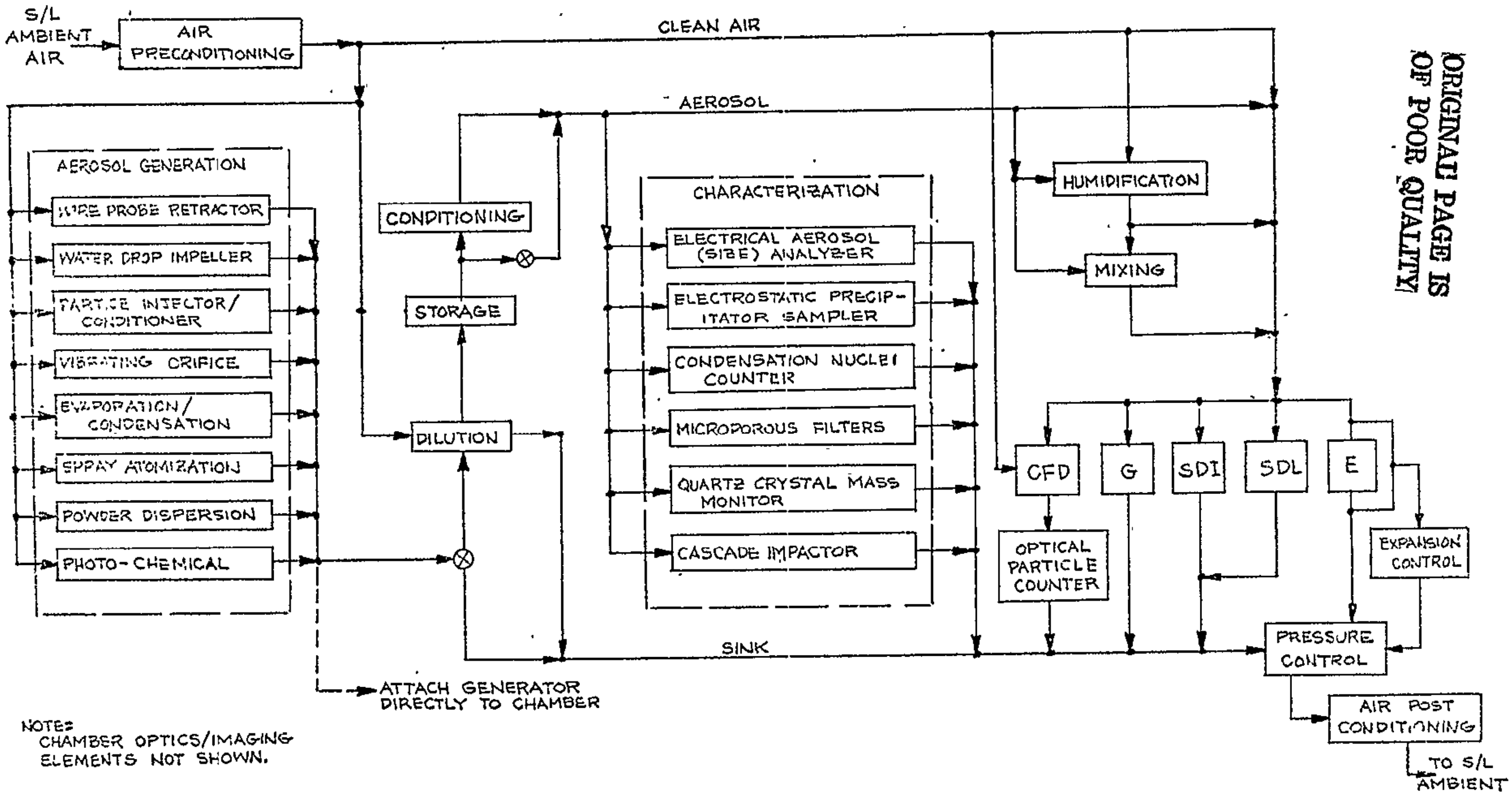
	EQUIPMENT CANDIDATES DEFERRED GROWTH*	ADVANCED EQUIPMENT
CHAMBERS	GENERAL SPECIAL	ELECTRIC FIELDS ACOUSTICAL FIELDS OPTICAL FIELDS POSITIONING (CONDITIONING/CONTROL ADVANCEMENTS)
PARTICLE GENERATORS	SPRAY ATOMIZER GENERATOR POWER DISPERSION GENERATOR WIRE PROBE RETRACTOR GENERATOR WATER DROP IMPELLER GENERATOR	PARTICLE INJECTOR AND SIZE CONDITIONER
PARTICLE DETECTORS AND CHARACTERIZERS	SCATTEROMETER QUARTZ CRYSTAL MASS MONITOR CASCADE IMPACTOR	LIQUID WATER CONTENT METER DROPLET SIZE DISTRIBUTION METER
OPTICAL AND IMAGING DEVICES	CINE CAMERA (35 MM) IR MICROSCOPE VILOCIMETER OPTICAL THERMOELECTRIC DEW POINT HYDROMETER	HOLOGRAPHY U.V. WATER PROFILE DETECTOR ADVANCED I.R. MICROSCOPE X-RAY, RAMAN
EXTENDED EXPERIMENT CAPABILITY	DIC (8), HN (9) SVP (11), NM (16)	IMPROVEMENT OF ALL AND CS (4), RA (7) CIF (10) DCB (17), CE (18)

* EXPERIMENT SELECTION DEPENDENT

FUNCTION EQUIPMENT LAYOUT (GROWTH)

As implied on the facing functional diagram, generators, characterizers and chambers can be attached and interchanged based on the particular mission objectives.

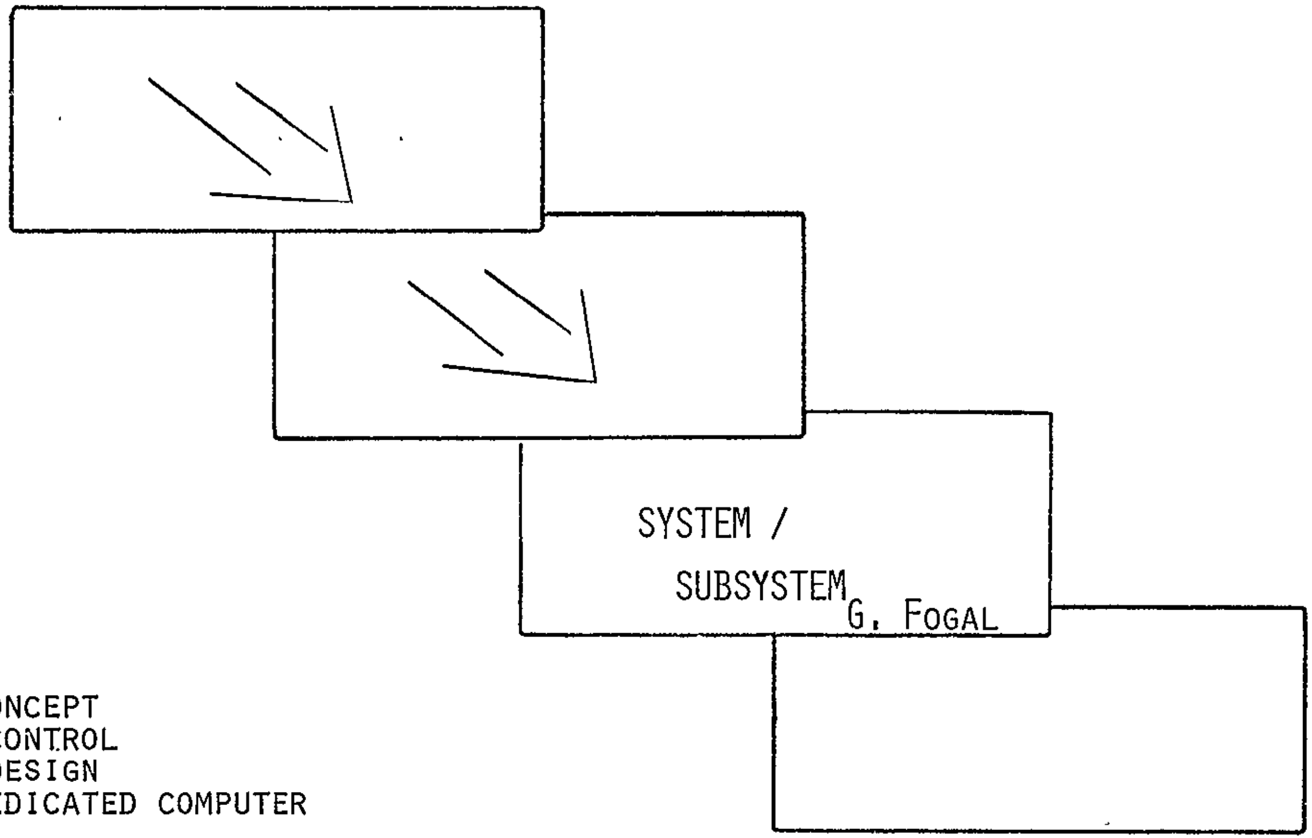
FUNCTIONAL EQUIPMENT LAYOUT (GROWTH)



NOTE: CHAMBER OPTICS/IMAGING ELEMENTS NOT SHOWN.

SPACE DIVISION

ACPL



STATUS

- SYSTEM CONCEPT
- THERMAL CONTROL
- WICKING DESIGN
- S/L VS DEDICATED COMPUTER

ACPL REQUIREMENTS/GUIDELINES

As presently envisioned, the Initial ACPL system design must accomodate cloud physics experiments using three types of cloud chambers, i.e. expansion, continuous flow diffusion and static diffusion liquid. The selection, sizing and installation of supportive equipments must be consistent with the future cost effective addition of an expansion in the Initial ACPL capabilities to a total capability ACPL. The system design must interface with and where practical make full use of available Spacelab Facilities and capabilities.

To accomodate as yet undefined experiment protocols, the system design must provide operational flexibility to accomodate the diverse range of test conditions which may be required by the principal investigators on each mission. Further, to assist the principal investigator in defining the experiment, one G (as well as zero G) operational capability is mandatory.

ACPL REQUIREMENTS/GUIDELINES

- o ACCOMODATE EXPERIMENTS ASSOCIATED WITH THREE CLOUD CHAMBER TYPES
  - EXPANSION CHAMBER
  - CONTINUOUS FLOW DIFFUSION CHAMBER
  - STATIC DIFFUSION LIQUID CHAMBER
- o PROVIDE GROWTH CAPABILITY
  - ALTERNATE CHAMBERS
  - ALTERNATE PARTICLE GENERATORS/CHARACTERIZERS
- o INTERFACE WITH SPACELAB FACILITIES
  - ELECTRICAL POWER/EXPMT. RACKS
  - DATA HANDLING AND CONTROL/THERMAL DISSIPATION
- o PROVIDE ZERO G / ONE G OPERATION
- o DESIGN FOR MISSION OBJECTIVE FLEXIBILITY

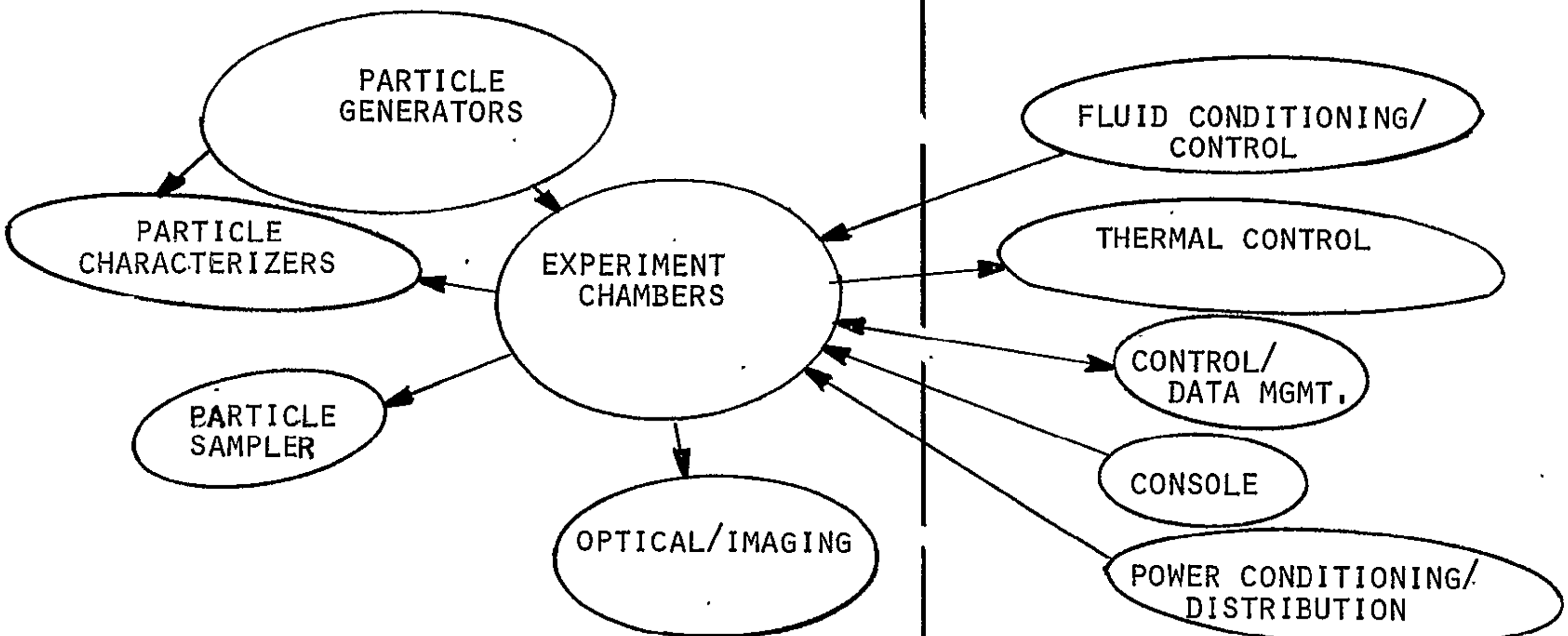
MISSION DEPENDENT/INDEPENDENT ELEMENTS

The basic ACPL system concept is to provide a flexible operating capability in order to accomodate the varying mission to mission experiment requirements. The system thus can be divided into mission dependent and mission independent elements. The mission dependent elements such as cloud chambers, particle generators and characterizers will vary depending on the principal investigators requirements. The independent elements will not change and thus, if cost effective, should initially be sized or be readily expandable to a full ACPL capability.

SYSTEM CONCEPT

MISSION DEPENDENT

MISSION INDEPENDENT



INTERFACE AREAS

The diagram shows the basic system elements in a functional arrangement and their respective interfares with the SpaceLab facilities

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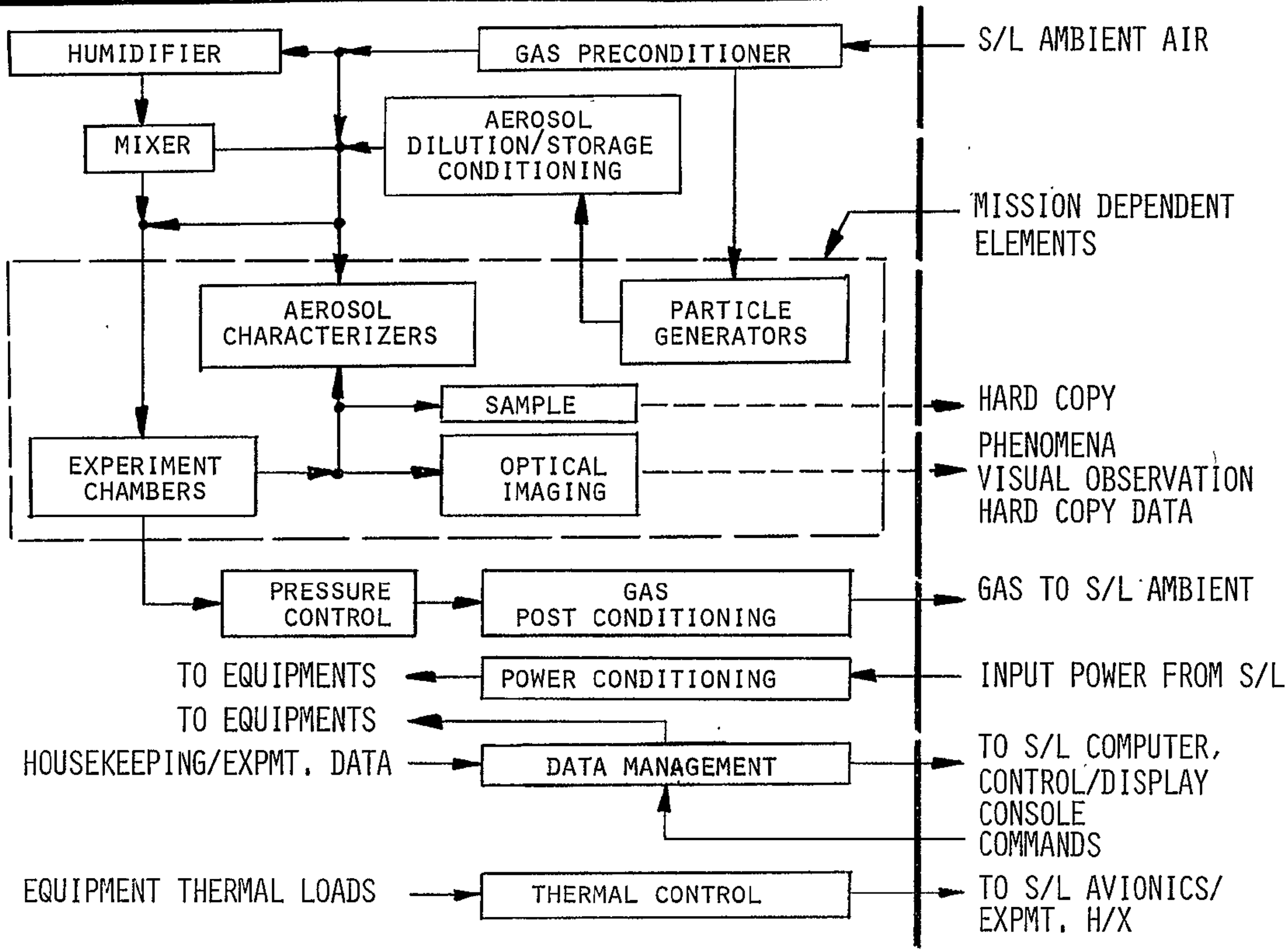
SYSTEM CONCEPT

ACPL



S/L RESOURCE SUMMARY

Available Spacelab Facilities and resources appropriate to the ACPL are summarized on the facing page. Note that these facilities and resources are available to all S/L experiments. Thus, the acceptability of ACPL as a S/A experiment will be enhanced if the use of S/L resources is minimized.

SPACE DIVISION

SPACELAB RESOURCE SUMMARY

ACPL

ELECTRICAL

O DC VOLTAGE	28 ± 4
O AC VOLTAGE	$115/200 \pm 3\%$
	400 ± 1 HZ
	3 PHASE

POWER

DC	4 KW AVG.
DC	2 KVA AVG.
COMBINATION	4 KW AVG.

THERMAL

O DISSIPATION	
ATMOSPHERE	1.0 KW MAX.
AVIONICS	3.0 KW MAX.
EXPMT. H/X	4.0 KW MAX.
O SINK TEMPERATURE	
ATMOSPHERE	18 TO 27 ^{o}C
AVIONICS AIR	20 TO 38 ^{o}C
EXPMT. H/X	18 TO 20 ^{o}C

ATMOSPHERE

O TEMPERATURE	18 TO 27 ^{o}C
O TOTAL PRESSURE	1013 ± 13 MB
O COMPOSITION	79% N_2/21% O_2
O RELATIVE HUMIDITY	25 TO 70%
O PARTICULATES	5 MICRON FILTER

EXPMT. RACK (DOUBLE)

O USEABLE VOLUME	1.28 M^3
O LOAD CAPACITY	525 KG

EXPMT. STORAGE

O CEILING LOCATION	
SIZE	0.1 M^3 x 8
LOADING	24 KG EACH

THERMAL CONTROL TRADE STUDY

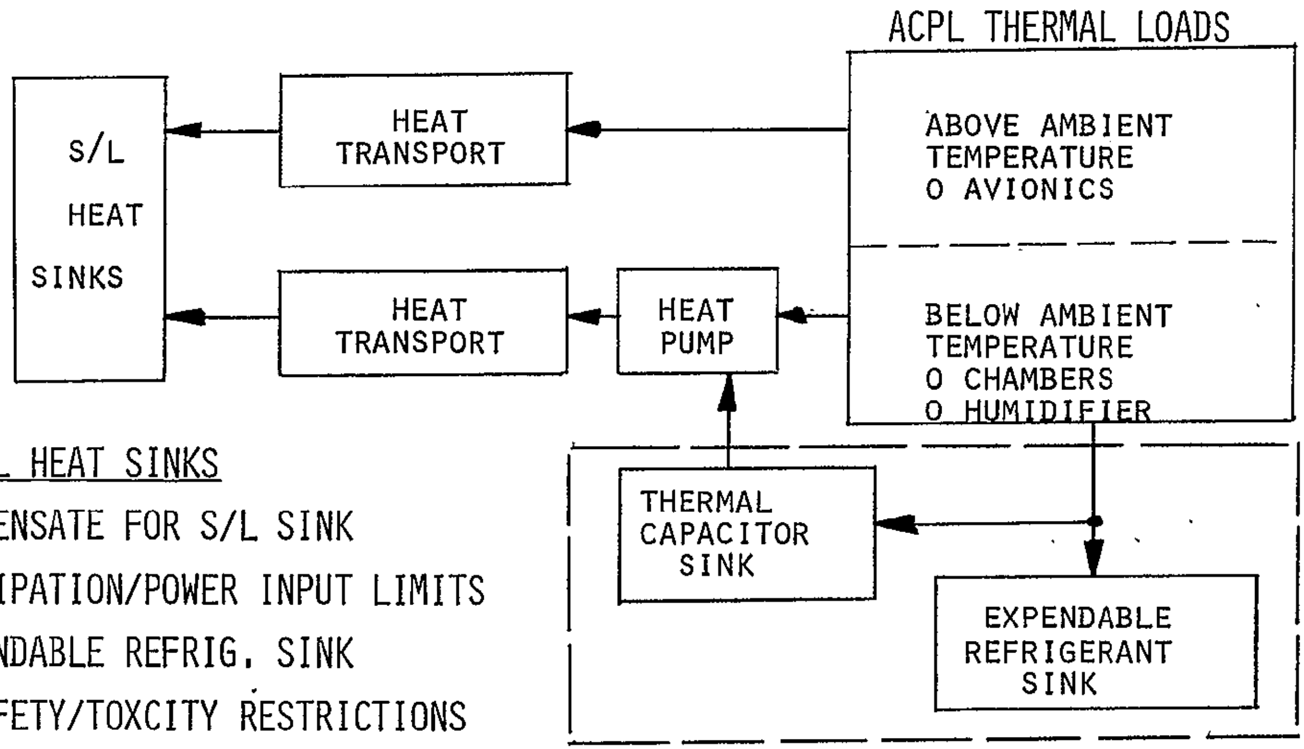
The Thermal Control subsystem represents a key trade-off area due to the design interactions between chamber and thermal control concepts. Subsequent charts briefly present the trade study activity completed in this area.

TRADE STUDY

- KEY SUBSYSTEM TRADE AREA
- CHAMBER DESIGN/THERMAL CONTROL CONCEPT INTERACTION

THERMAL CONTROL-SUPPLEMENTAL HEAT SINKS

The thermal control problem is basically one of collecting thermal energy from the various ACPL thermal loads, transporting this thermal energy to the S/L heat sink and dissipating the energy into the S/L heat sinks. Two general types of ACPL thermal loads are evident, the above ambient temperature avionics thermal load and the below ambient thermal loads represented by the cloud chambers and humidifier. Since the dissipation capacity of the S/L heat sinks is limited, supplemental heat sinks may be required. Expendable refrigerants and thermal capacitors are two examples of supplementary sinks which may be appropriate for ACPL.



SUPPLEMENTAL HEAT SINKS

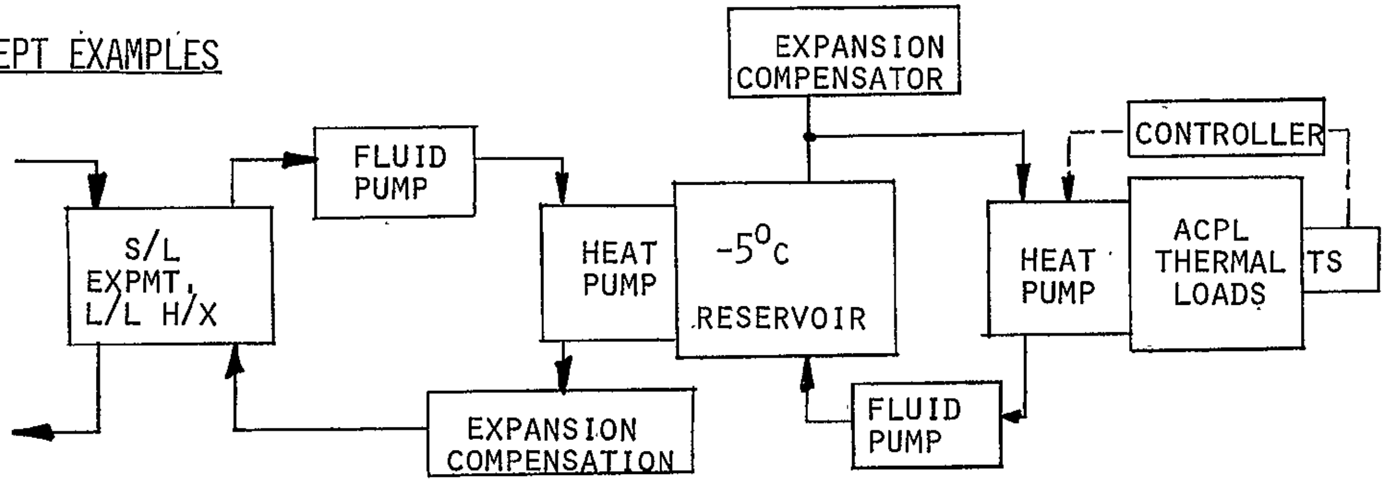
- o COMPENSATE FOR S/L SINK DISSIPATION/POWER INPUT LIMITS
- o EXPENDABLE REFRIG. SINK
  - SAFETY/TOXCITY RESTRICTIONS
  - STORABILITY (PRELAUNCH/ORBITAL OPS.)
  - OVERBOARD DISPOSAL RESTRICTED DEPENDING ON OTHER EXPMTS.
  - STORAGE LOCATION
- o THERMAL CAPACITOR SINK
  - REGENERABLE DURING ORBITAL OPS.

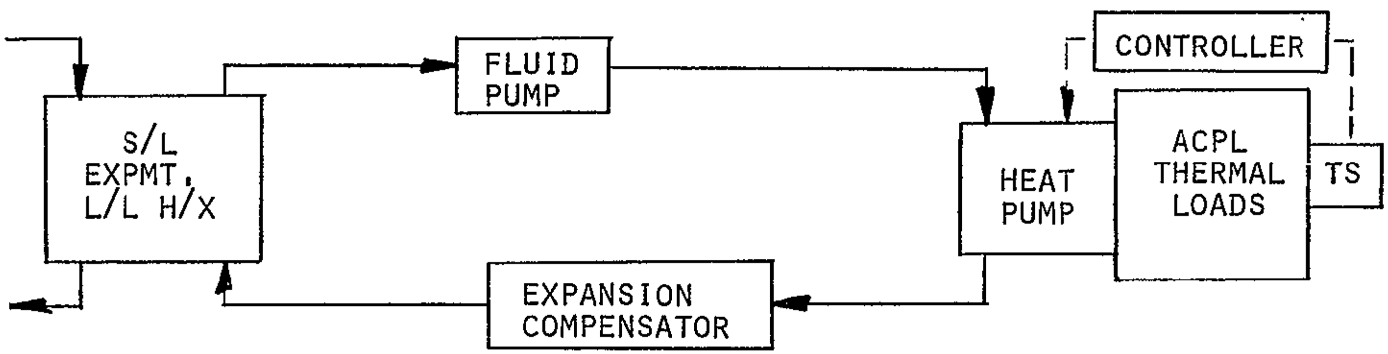
THERMAL CONTROL CONCEPT EXAMPLES

The two thermal control concepts shown are examples of equipment configuration required for collecting, transporting and dissipating the thermal energy from below ambient temperature thermal loads (cloud chambers, humidifier). The two concepts shown are similar, the upper diagram showing a two stage version of the lower concept. Many other control concepts are possible and may be applicable to the ACPL. In applying selection criteria, the entire thermal collection, transport and dissipation process must be considered for valid results.

THERMAL CONTROL

CONTROL CONCEPT EXAMPLES





SELECTION CRITERIA

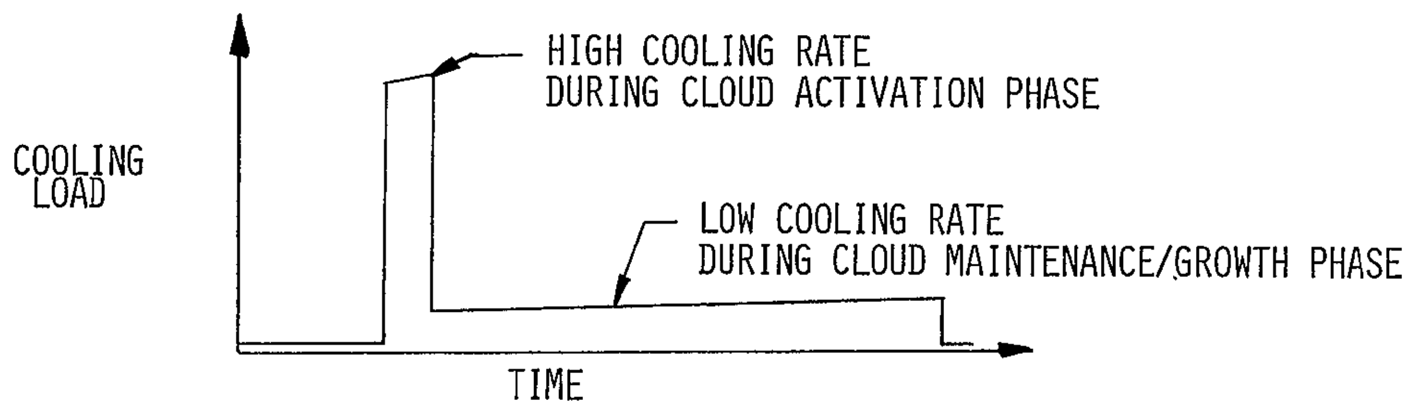
- O WEIGHT/VOLUME/POWER
- O DEVELOPMENT RISK
- O RELIABILITY/SAFETY
- O REOCCURING/NON-REOCCURING COST
- O ACPL GROWTH CAPABILITY

ACPL THERMAL LOADS - WORSE CASE

Preliminary analyses of the various ACPL thermal loads indicated that the expansion chamber represents the worse case situation. This is true for two reasons, the high cooldown rate coupled with close temperature uniformity of the chamber walls. The time/load profile shown typifies the expansion chamber thermal load condition. On the assumption that a thermal control solution for the expansion chamber will be readily adaptable to the other cloud chambers and humidifier (a likely assumption and one which maximizes commonality), exploratory analyses of four thermal control concepts have been completed and are briefly summanized on the following pages.

ACPL THERMAL LOADS

- o EXPANSION CHAMBER WORSE CASE
  - HIGH COOLING RATE WITH CLOSE TEMPERATURE UNIFORMITY
- o TYPICAL TIME/THERMAL LOAD PROFILE



EXPLORATORY ANALYSES

- o FOUR CONTROL CONCEPTS ANALYZED

CASE 1 - PUMPED COOLANT
CASE 2 - PUMPED COOLANT/HEAT PIPE COMBINATION
CASE 3 - TE HEAT PUMP
CASE 4 - TE HEAT PUMP/HEAT PIPE COMBINATION

THERMAL CONTROL - PUMPED COOLANT

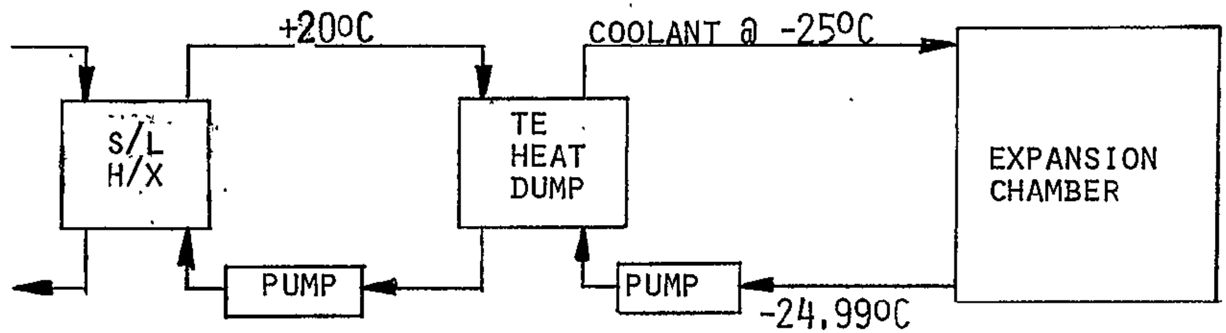
The facing chart shows subsystem analysis results for a pumped coolant concept. Note that the temperature non-uniformity is 0.02°C. The numerical results shown are approximations suitable for first cut comparisons (as are similar results in subsequent charts).

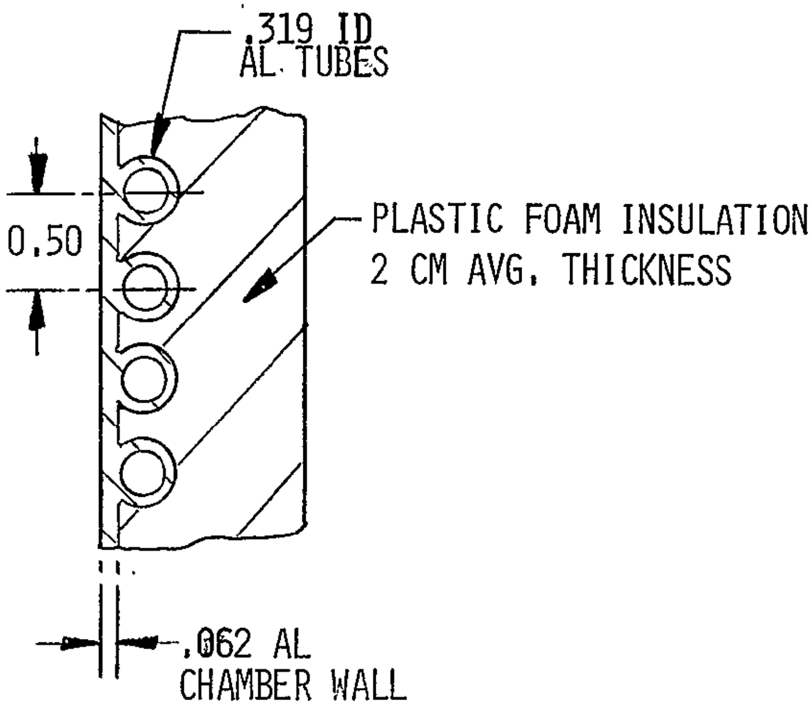
SPACE DIVISION

THERMAL CONTROL

ACPL

CASE 1





SUBSYSTEM ANALYSIS RESULTS

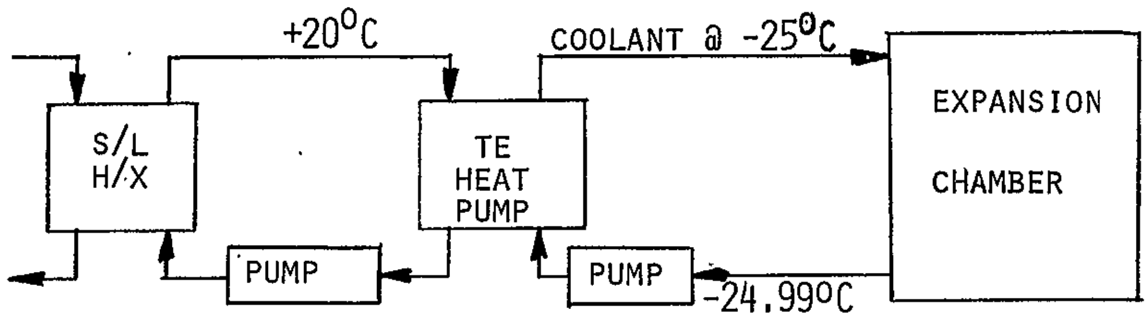
CHAMBER	
COOLED WEIGHT	21 LBS
MAX. TEMP. NON-INFORMITY	0.02°C
COOLANT TUBES	100
COOLING LOAD	
@ 6°C/MIN. RATE	0.57 KW
@ 0.5°C/MIN. RATE	0.03 KW
POWER INPUT, MAX.*	
TE HEAT PUMP	2.5 KW
PUMP	4.0 KW
TOTAL	6.5 KW

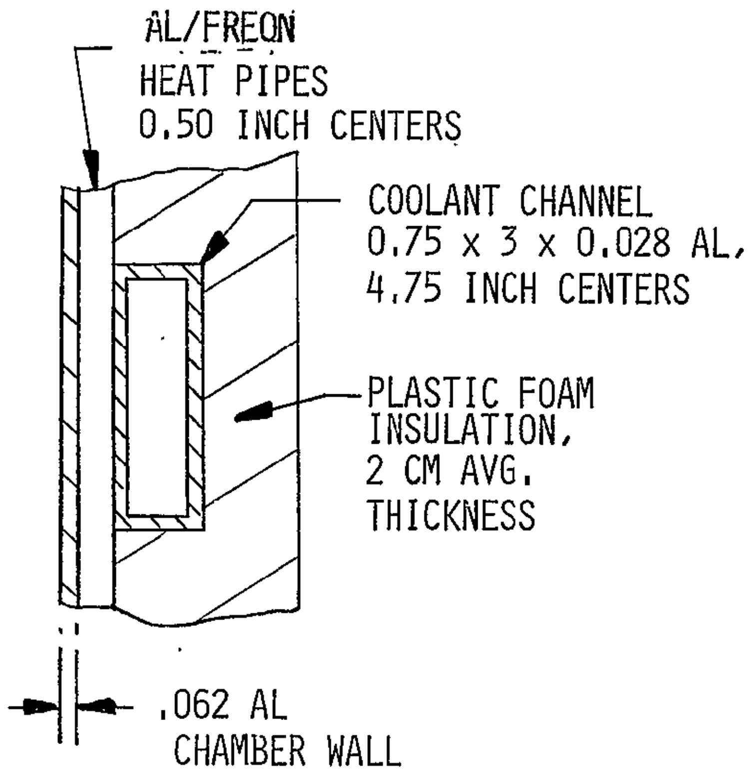
*FOR 6°C/MIN. COOLDOWN

THERMAL CONTROL - PUMPED COOLANT PLUS HEAT PIPES

The results for a pumped coolant, heat pipe combination show a significant power reduction (mainly a reduction in pump power accomplished by larger coolant channels). Temperature uniformity also has been improved by addition of the heat pipes (to $0.01^{\circ}C$). TE heat pump power increased due to the larger mass to be cooled (35 lbs. vs 21 lbs. for the pumped coolant concept).

CASE 2





SUBSYSTEM ANALYSIS RESULTS

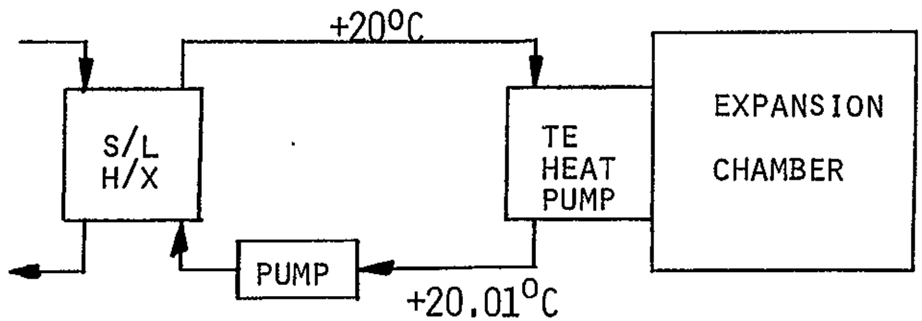
CHAMBER	
COOLED WEIGHT	35 LBS.
MAX. TEMP. NON-UNIFORMITY	0.01°C
COOLANT CHANNELS	8
HEAT PIPES	48
COOLING LOAD	
@ 6°C/MIN. RATE	0.76KW
@ 0.5°C/MIN. RATE	0.04KW
S/S POWER INPUT, MAX.*	
TE HEAT PUMP	3.4KW
PUMP	0.7KW
TOTAL	4.1KW

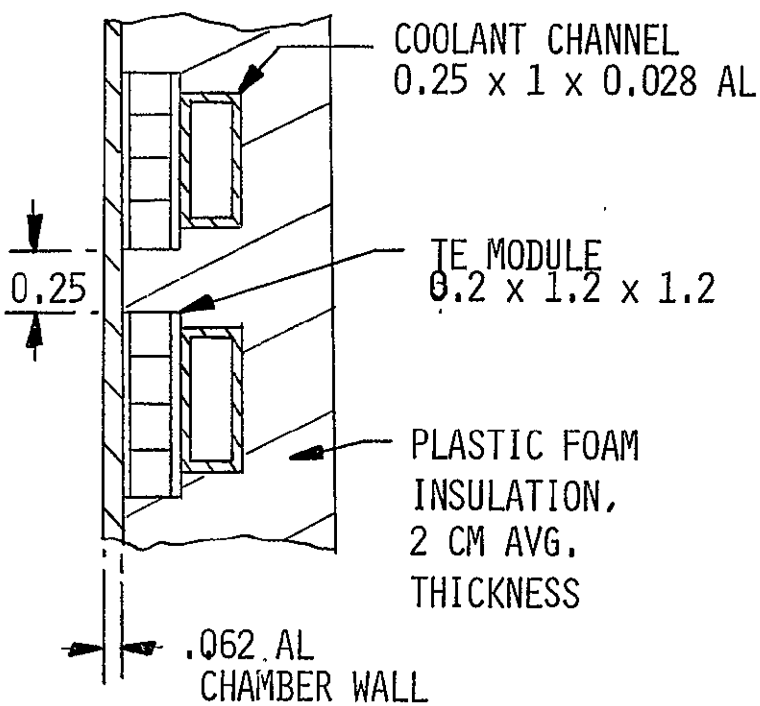
*FOR 6°C/MIN. COOLDOWN

THERMAL CONTROL - TE HEAT PUMP

This chart presents results for a TE heat pump concept. Note that although peak power is about half that for the preceeding concepts, temperature non-uniformity increased to 0.1°C.

CASE 3





SUBSYSTEM ANALYSIS RESULTS

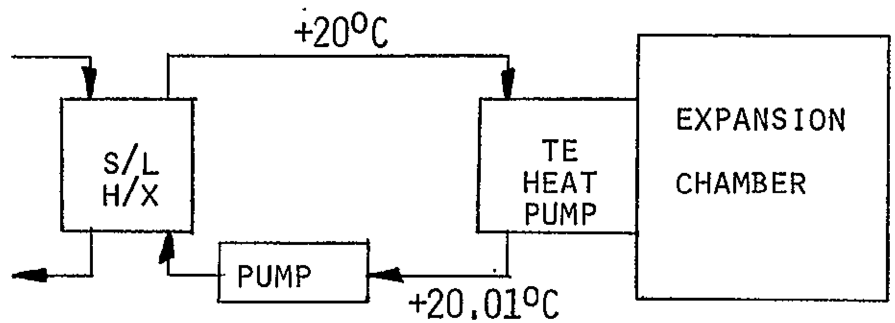
CHAMBER	
COOLED WEIGHT	25 LBS.
MAX. TEMP. NON-INFORMITY	0.10°C
COOLANT CHANNELS	36
TE MODULES	450
COOLING LOAD	
@ 6°C/MIN. RATE	0.32
@ 0.5°C/MIN. RATE	0.02
S/S POWER INPUT, MAX.*	
TE HEAT PUMP	1.0 KW
PUMP	1.3 KW
TOTAL	2.3 KW

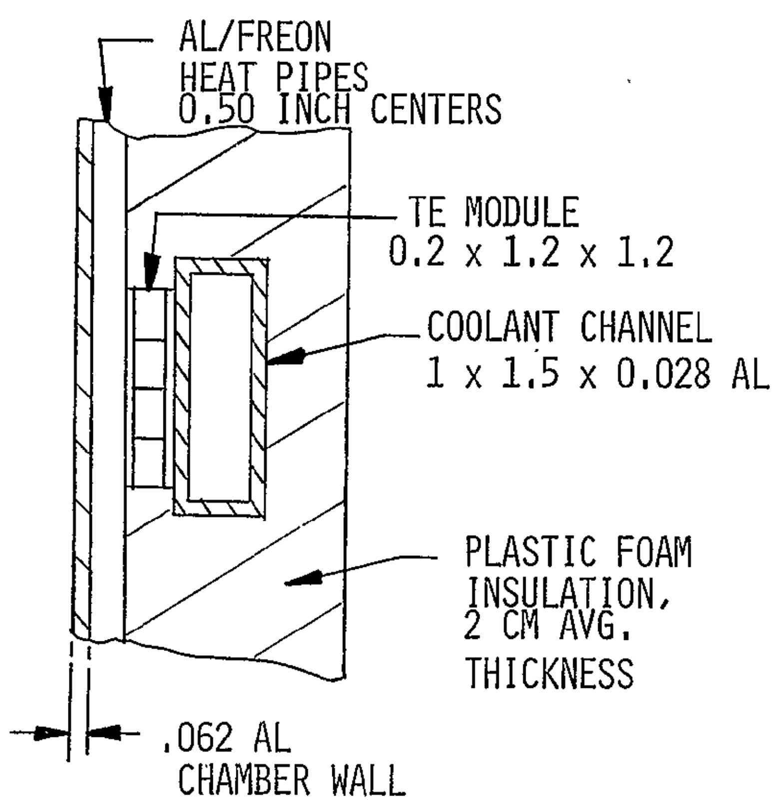
*FOR 6°C/MIN. COOLDOWN

THERMAL CONTROL - TE HEAT PUMP PLUS HEAT PIPES

Peak power and temperature non-uniformity for the combination of TE heat pump/ heat pipes approximates that for the pumped coolant/heat pipe combination concept summarized on a previous chart.

CASE 4





SUBSYSTEM ANALYSIS RESULTS

CHAMBER	
COOLED WEIGHT	26 LBS.
MAX. TEMP. NON-UNIFORMITY	0.01°C
COOLANT CHANNELS	8
TE MODULES	120
HEAT PIPES	48
COOLING LOAD	
@ 6°C/MIN. RATE	0.62 KW
@ 0.5°C/MIN. RATE	0.03 KW
S/S POWER INPUT, MAX.*	
TE HEAT PUMP	2.2 KW
PUMP	1.9 KW
TOTAL	4.1 KW

*FOR 6°C/MIN. COOLDOWN

THERMAL CONTROL - EFFECT OF TEMPERATURE UNIFORMITY

In the preceeding analyses, chamber wall temperature non-uniformity varied from 0.1° to 0.01°C. This chart shows the reduction in peak power resulting in a relaxation of the wall temperature non-uniformity to 0.1°C.

TEMPERATURE UNIFORMITY EFFECT

CASE	S/S POWER/TEMP NON-UNIFORMITY	
1 - PUMPED COOLANT	6.5 KW @ 0.02°C	2.2 KW @ 0.10°C
2 - PUMPED COOLANT/ HEAT PIPE COMB.	4.1 KW @ 0.01°C	2.5 KW @ 0.10°C
3 - TE HEAT PUMP	2.3 KW @ 0.10°C	2.3 KW @ 0.10°C
4 - TE HEAT PUMP/ HEAT PIPE COMB.	4.1 KW @ 0.01°C	1.6 KW @ 0.10°C

THERMAL CONTROL - SUMMARY

In summary, the expansion chamber was determined to be the worse cáse thermal control problem due to the high cooldown rate coupled with close wall temperature uniformity. Comparatively the TE Heat pump/heat pipe concept exhibits lowest peak power of the concepts analyzed. Additional design refinement is necessary to reduce peak power (for the expansion chamber) below a 1.0 KW goal.

STATUS SUMMARY

- EXPANSION CHAMBER REPRESENTS WORSE CASE THERMAL CONTROL PROBLEM
  - 6°C/MIN COOLING RATE WITH TEMPERATURE UNIFORMITY
- ELECTRICAL POWER INPUT EXCESSIVE FOR EXPANSION CHAMBER THERMAL CONTROL CONCEPTS ANALYZED
  - RANGE 1.6 TO 6.5 KW
- DESIGN REFINEMENT/ALTERNATE CONCEPT ANALYSIS TO REDUCE ELECTRICAL POWER INPUT
  - MINIMIZE CHAMBER COOLING LOAD; PUMP/TEM PWR.
    - THERMAL CAPACITOR/EXPENDABLE REFRIGERANT
  - RELAX CHAMBER THERMAL REQMTS.
    - COOL DOWN RATE/UNIFORMITY
- ELECTRICAL POWER INPUT GOAL
  - 1.0 KW MAX.

WICKING DESIGN TRADE STUDY

Trade study results, which apply to the design of the humidifier and CFD/ SDL cloud chambers, are summarized on subsequent charts.

TRADE STUDY

- o KEY TRADE AREA
- o APPLICATION TO CLOUD CHAMBERS HUMIDIFIER

WICKING DESIGN - APPLICATION

The generation of temperature controlled, wetted surfaces is an important design consideration for the humidifier and CFD/SDL chambers. The wick type surface concept used in existing laboratory units appears adaptable to the ACPL operational environment. Design and construction of the wick surface and associated water storage capability are the significant trade study areas.

WICKING DESIGN

APPLICATION

- CFD CHAMBER
- HUMIDIFIER
- SDL CHAMBER

REQUIREMENTS

- MAX. WATER USE RATE

APPLICATION	DRY AIR FLOW RATE	WATER USE RATE
CFD CHAMBER	50 ML/SEC	0.0013 GM/SEC
HUMIDIFIER	1 L/SEC	0.025 GM/SEC

- ZERO G/ONE G OPERATION
- COMPATABLE WITH LAUNCH/REENTRY CONDITIONS
- CLEANABLE
- GROWTH PROVISION

PROBLEM AREAS

- WATER STORAGE QUANTITY/LOCATION
- WICK CONSTRUCTION
- CONTAMINATE BUILD-UP

WICKING DESIGN - WATER STORAGE

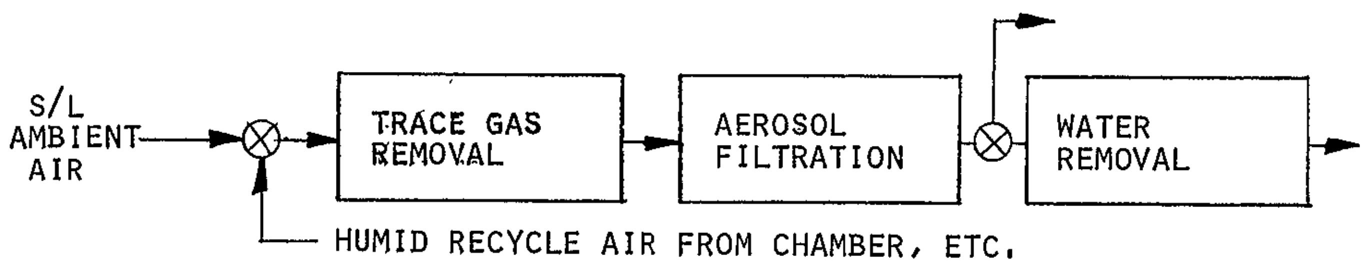
The CFD chamber and humidifier are the significant water users. Water storage requirements can be reduced by a by-pass air flow arrangment as shown. Where operating conditions permit, humid ambient and/or recycle air (after trace gas removal and aerosol filtration) can be circulated directly to the CFD or humidifier. If sophisticated enough controls are provided, very little stored water would be required.

WATER STORAGE

- STORAGE CAPACITY REQUIRED (MAX.)

APPLICATION	MISSION USAGE	
	30 HOURS	120 HOURS
CFD CHAMBER	0.14 KG	0.56 KG
HUMIDIFIER	2.7 KG	10.8 KG

- RECIRCULATION OPTION

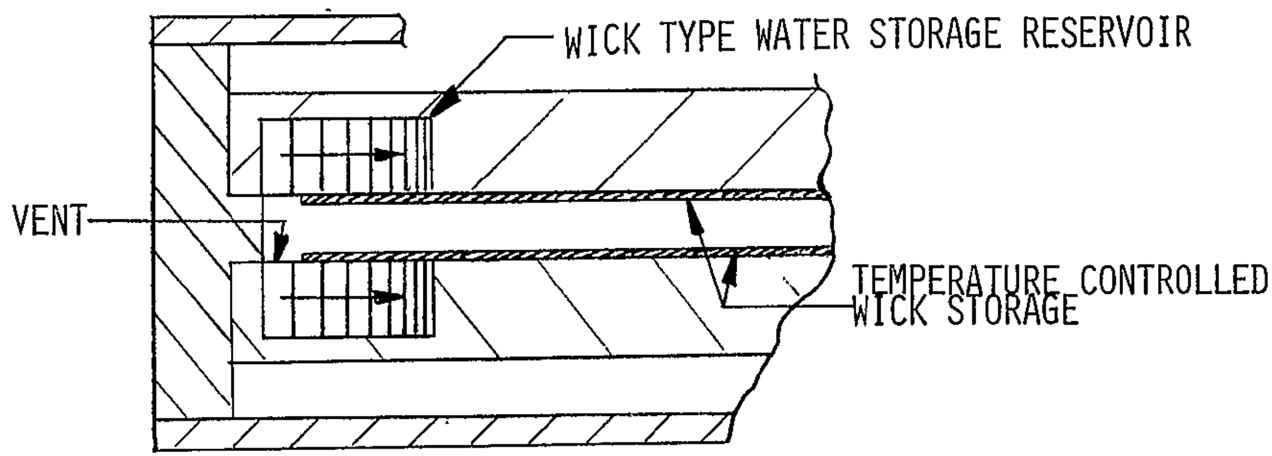


- ALLOWABLE BYPASS FLOW FUNCTION OF HUMIDIFIER OPERATING TEMPERATURE
- WATER USE REDUCTION FUNCTION OF BYPASS FLOW CONTROL SOPHISTICATION
- ADDED MECHANICAL/CONTROL COMPLEXITY

WICKING DESIGN - INTEGRAL WATER STORAGE

Water storage may be provided by use of wick type reservoirs integral with the chamber or humidifier structure. Graded capillarity plus an air vent are required in the reservoirs to insure full use of the stored water. A by-pass airflow arrangement (see previous chart) would be advantages in reducing reservoir volume, particularily for long duration missions. Reservoir fill during orbit operations is operationally undesirable but possible using FSE equipment.

WICKING DESIGN



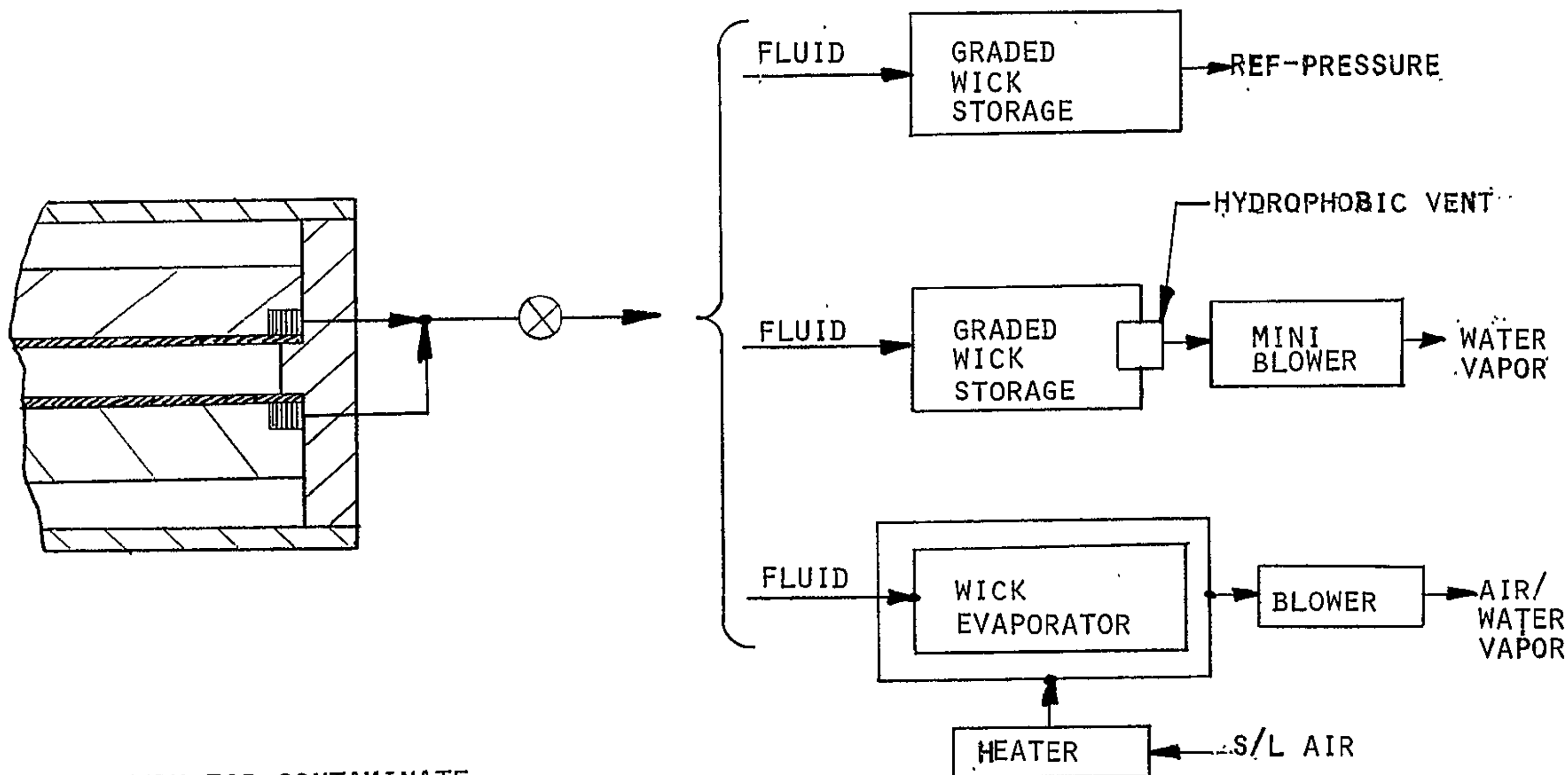
<u>WATER STORAGE INTEGRAL WITH CFD CHAMBER/HUMIDIFIER</u>

- o GRADED CAPILLARITY REQUIRED IN RESERVOIR
- o AUTOMATIC RESERVOIR AIR VENT REQUIRED (TO COMPENSATE FOR EVAPORATED WATER)
- o BYPASS FLOW CAN REDUCE RESERVOIR VOLUME REQ'D
- o RESERVOIR ADDS TO THERMAL LOAD
- o GROWTH/EXTENED MISSION DURATION REQUIRES REDESIGN OR INITIAL PENALTY
- o COMPATABLE ONE G/ZERO G OPERATION REQUIRES RESERVOIR FILL DURING ORBIT OPERATIONS
  -ON PAD/LAUNCH REENTRY ORIENTATION

WICKING DESIGN - CONTAMINATE BUILD-UP PREVENTION

The facing page shows several candidate options for providing a continuous water flow thru the chamber or humidifier wick surfaces.

WICKING DESIGN



- FLOW THRU FOR CONTAMINATE BUILD-UP PREVENTION

DATA MANAGEMENT TRADE STUDY

The key trade in the data management area involves the use of a dedicated computer, i.e. integral with ACPL, vs use of the Spacelab computer. Both hardware and software factors must be considered.

TRADE STUDY

- KEY TRADE AREA
- DEDICATED VS SPACELAB COMPUTER

DATA MANAGEMENT

Candidate DMS configurations have been considered with three general concepts selected for further analysis. These candidate configurations are in three catagories: (1) all data processing/control accomplished via the S/L computer, (2) all processing/control integral to the ACPL and (3) combinations of the above. The first two categories represent extreme conditions which serve to bound the analysis effort.

SPACE DIVISION

ACPL

DATA MANAGEMENT

<u>CANDIDATE CONFIGURATIONS</u>

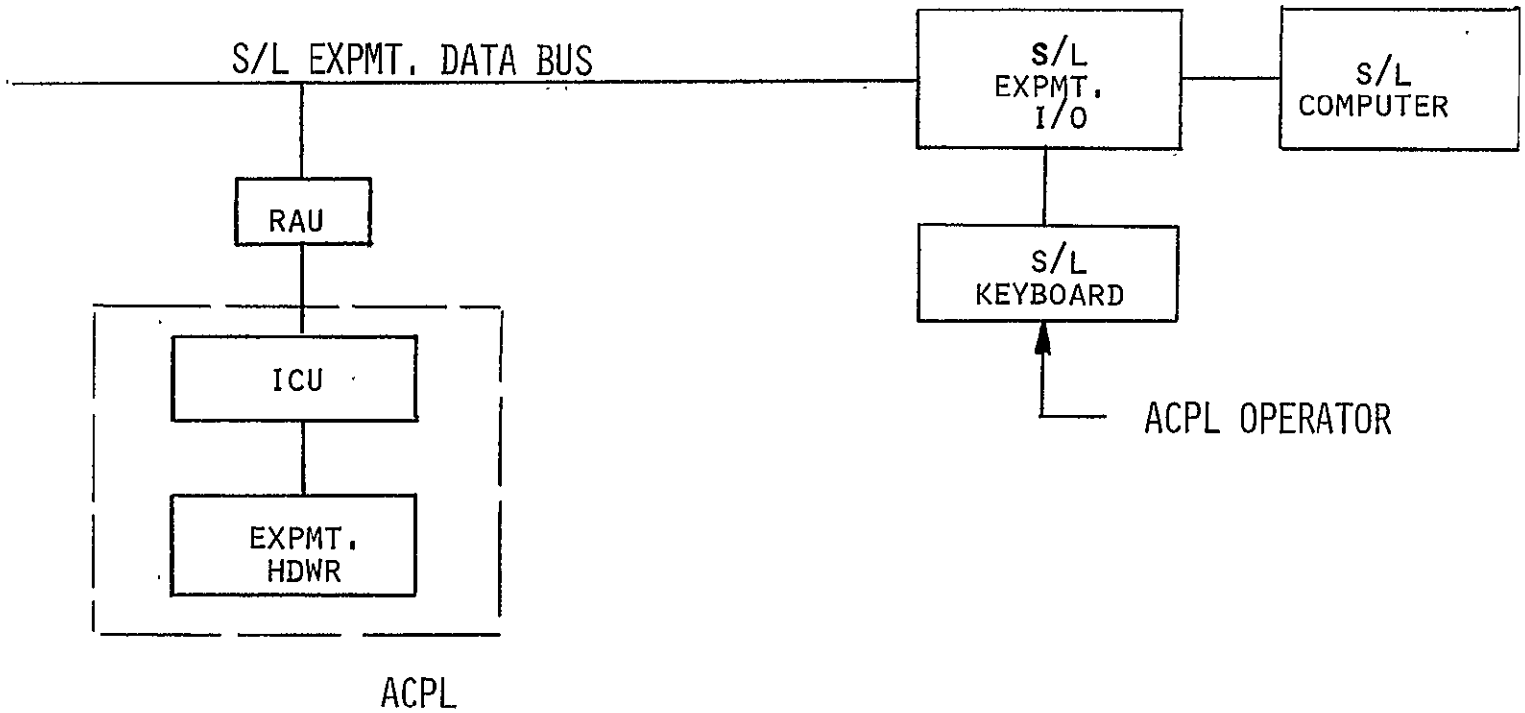
- ALL PROCESSING/CONTROL VIA S/C COMPUTER
- ALL PROCESSING/CONTROL WITHIN ACPL
- COMBINATION

<u>DECISION CRITERIA</u>

- COMPUTER LOADING
  - DATA MONITORING
  - COMMAND INITIATION
  - COMPUTATIONS/DATA PROCESSING
- SPECIAL SOFTWARE REQMT.
- WEIGHT/VOLUME/POWER
- RELIABILITY
- GROWTH CAPABILITY
- COST EFFECTIVENESS

DATA MANAGEMENT

This chart presents the condition wherein all ACPL data processing and control is accomplished using the S/L computer.. In this concept, the ACPL operator interface for test sequence initiation is at the S/L keyboard. Note that this concept minimizes ACPL DMS hardware but maximizes dependence on S/L hardwares.



ALL PROCESSING/CONTROL VIA S/L COMPUTER

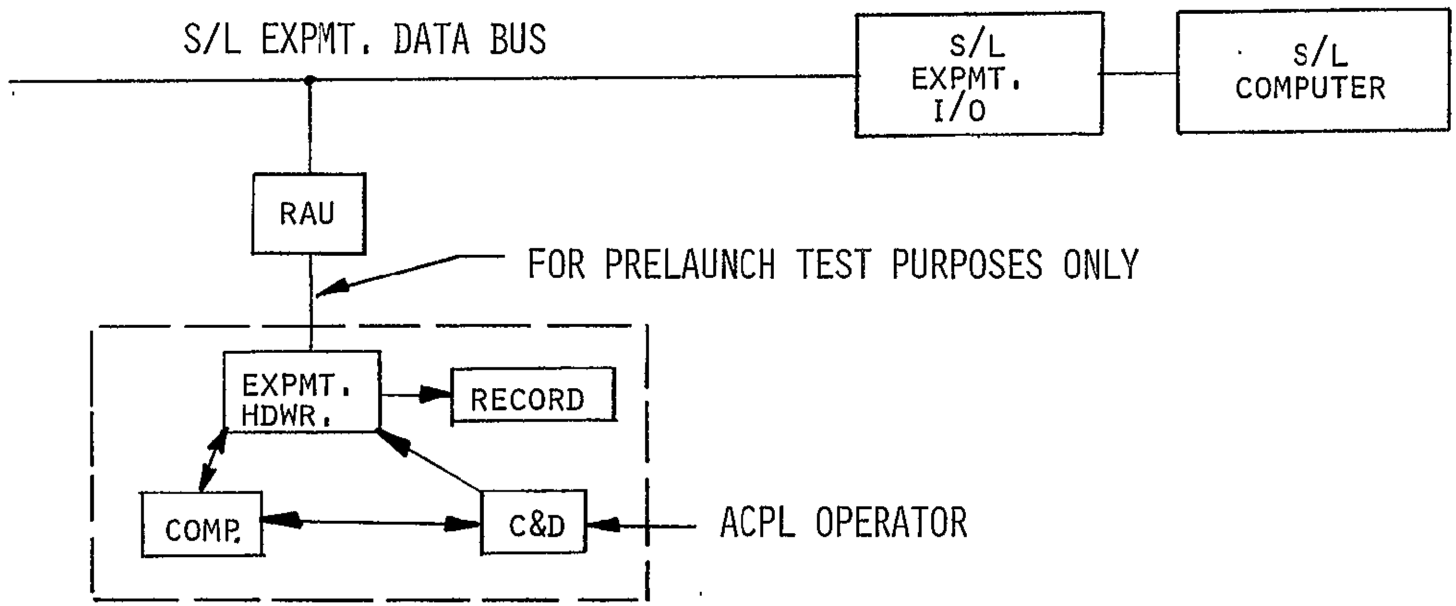
- DEPENDENT ON S/L COMPUTER
- SENSITIVE TO OTHER EXPMT. REQMTS.
- POTENTIAL LIMIT ON ACPL OPERATIONS
- MINIMUM ACPL HARDWARE

DATA MANAGEMENT VIA ACPL COMPUTER

Locating all DMS hardware integral to the ACPL minimizes dependency on the Spacelab but maximizes ACPL required hardware. This may be offset by software considerations.

SPACE DIVISION

DATA MANAGEMENT



<u>ALL PROCESSING/CONTROL WITHIN ACPL</u>

- INDEPENDENT OF S/L COMPUTER
- INSENSITIVE TO OTHER EXPMT. REQMTS.
- ISOLATE ACPL SOFTWARE
- MAXIMUM ACPL HARDWARE

SPACE DIVISION

ACPL

SUMMARY

R. GRECO

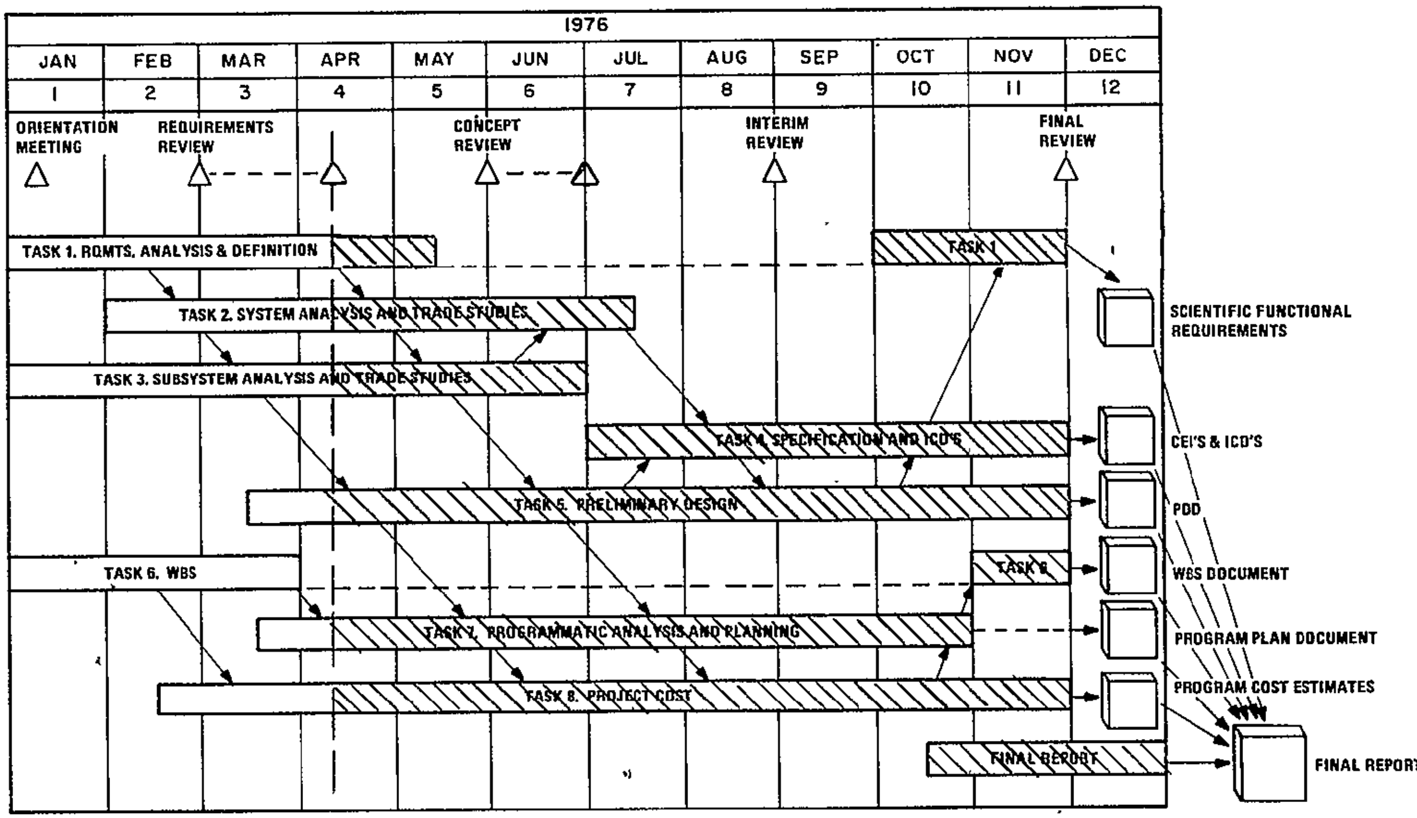
ACPL STUDY SUMMARY FLOW

The remainder of the study to be accomplished is shown on the schedule. The pacing items for these efforts is the finalization of the Scientific Functional Requirements for the Initial ACPL.

SPACE DIVISION

ACPL STUDY SUMMARY FLOW

ACPL



- STUDY PLAN
- WBS
- GROUND RULES AND GUIDELINES
- PERFORMANCE REQUIREMENTS

- SCIENCE REQUIREMENTS (PRELIMINARY)
- FLIGHT & GROUND SUPPORT EQUIPMENT REQUIREMENTS (PRELIM)
- MISSION/PAYLOAD REQUIREMENTS (PRELIM)
- COST TARGETS

- SCIENCE EQUIPMENT REQUIREMENTS
- FLIGHT & GROUND SUPPORT EQUIPMENT CONCEPT
- MISSION & PAYLOAD PLAN (PRELIMINARY)
- SYS/SUBSYS ANALYSIS & TRADES
- PERFORMANCE/COST ESTIMATES (PRELIM)
- OPERATIONS ANALYSIS (PRELIMINARY)
- IDENTIFICATION OF CRITICAL AREAS/ COMPONENTS

- PRELIM CEI'S & ICD'S ON HARDWARE FOR INITIAL FLIGHTS
- INTERIM DESIGN OF FLT & GROUND SUPPORT EQPT FOR INITIAL FLIGHTS
- INTERIM DESIGN OF LAB FOR INITIAL FLIGHTS
- INTERIM COST ESTIMATE
- COMPATABILITY WITH FOLLOW ON FLIGHT PROGRAM

- PAYLOAD DEFINITION
- PRELIMINARY DESIGN FOR INITIAL PAYLOAD & SUPPORT EQUIPMENT
- PRELIMINARY CEI'S AND ICD'S
- OPERATIONS ANALYSIS (FINAL)
- COST ESTIMATES (FINAL)
- RISK ANALYSIS
- IDENTIFY LONG LEAD PROCUREMENT ITEMS

GENERAL ELECTRIC